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LATITUDE DETERMINATION

By

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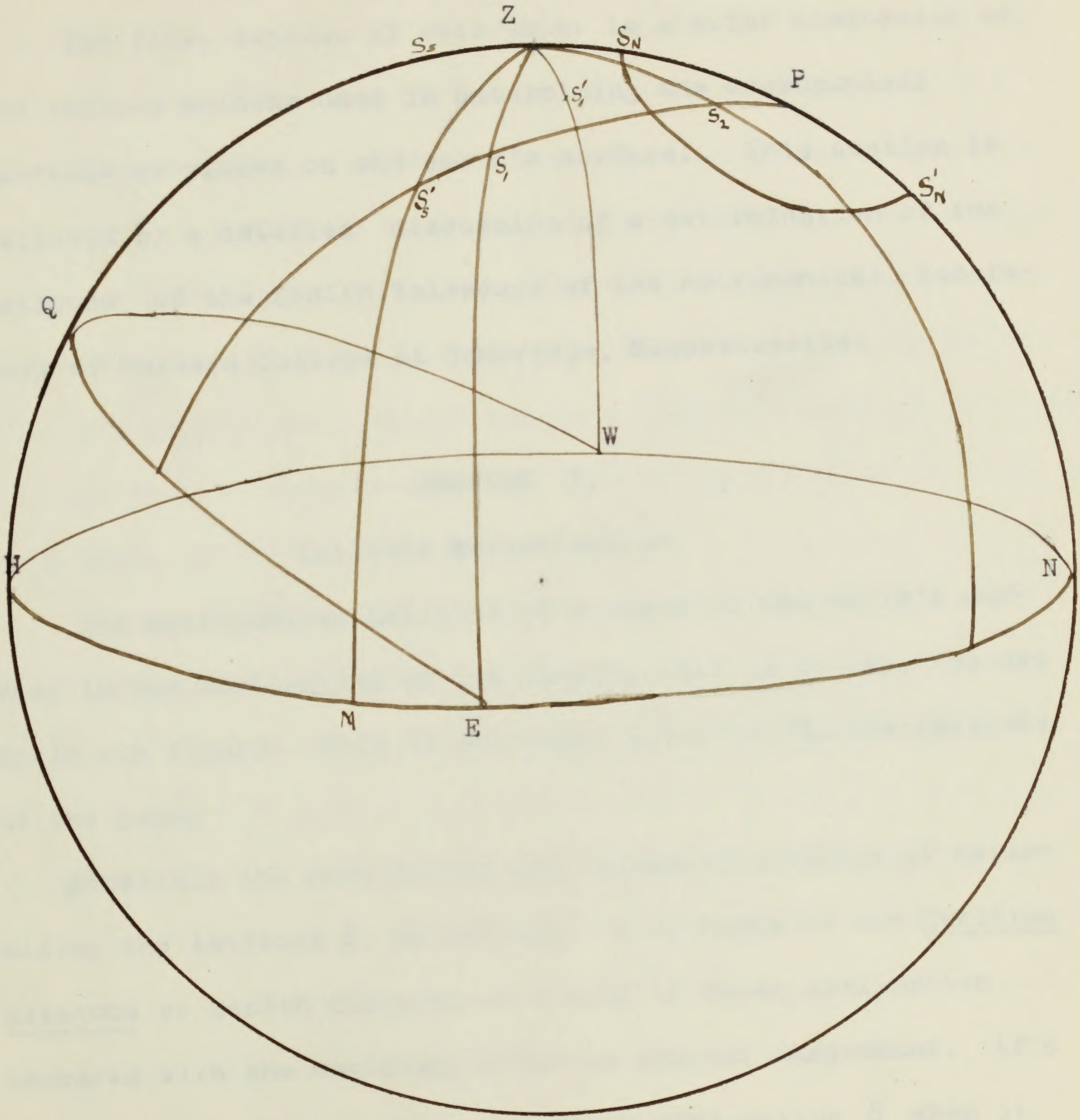

CELESTIAL SPHERE.

Z, zenith. P, pole. HWNE, horizon. EQW, equator.
EZW, prime vertical.

INTRODUCTORY.

The first section of this paper is a brief discussion of the various methods used in determining the astronomical latitude of places on the earth's surface. This section is followed by a detailed discussion of a determination of the latitude of the Zenith Telescope of the Astronomical Laboratory of Harvard College at Cambridge, Massachusetts.

SECTION I.

Latitude Determination.

The Astronomical Latitude of a place on the earth's surface is the declination of its zenith, that is to say, the arc ZQ in the figure. This is obviously equal to PN, the altitude of the pole.

#Possibly the most direct and fundamental method of determining the latitude ϕ, as defined, is by means of the Meridian Altitude or zenith distance of a star of known declination measured with the meridian circle or similar instrument. If ζ is the zenith distance of a star of declination δ when it crosses the meridian then,

$$\phi = \delta \pm \zeta \qquad (1)$$

the sign depending on whether the star is north or south of the zenith.

\# Special methods, such as those used at sea, approxima-

If it is not convenient to observe the star when it crosses the meridian, its altitude at some other known time may be observed, (as $S'M$), and the triangle ZPS solved for the co-latitude ZP. A study of the effect of errors in the observed altitude and time upon the resulting values of the latitude, (See Chauvenet's Astronomy, Vol. I, Art. 166.), shows that the effect is at a minimum when the observation is in the meridian, (i.e. when the first of the suggested methods is used), and at a maximum when it is in the prime vertical. It is also shown that the mean of two results obtained from altitudes of the same star at equal distances east and west of the meridian is free from small errors in the time.

In the geodetic surveys of France and Germany, latitude determination by means of circum-meridian altitudes has been much used as a result of the conslusions ~~of~~ stated in the last paragraph. In this method a number of observations are made on a star on either side of the meridian, at such times that pair by pair they are at equal distances from it. These observations may be reduced to the meridian in any one of several ways, the methods of Delambre and of Gauss being among those most commonly used.

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tions, and the various altitude methods by means of which the time as well as latitude is found, are not germane to the discussions of this paper and are not included in it. The same may be said of the detailed descriptions of methods of observation, of reductions, and of the special formulae used.

For such discussions see Chauvenet's Astronomy.

It will be noticed that in the methods discussed thus far the declination of the star enters as an important factor. Any error in declination is introduced directly into the resulting latitude. The effect of such error on the latitude determined from an altitude observation at known time is at a minimum when the star used is a circum-polar at elongation. The latitude as determined from the altitude of Polaris, S_2 , is thus largely free from declination errors. The reduction to the meridian is easily performed. In this method, however, as well as in the others discussed to this time the uncertainties of refraction are an important factor in determining the accuracy of the results.

In 1824 Bessel first pointed out the advantages of the use of the prime vertical in determining latitude. Half the time interval between the transit of a star across the prime vertical east and the prime vertical west gives the hour-angle In the right spherical triangle ZPS from which the co-latitude ZP may be determined if the declination is known. Moreover it is apparent from the solution that if the declination and latitude are nearly equal, i. e. if the star passes near the zenith, any error in the time will effect the resulting latitude but little. Any constant error in the clock correction will obviously have no effect on the result in any event. And from the considerations suggested above an error in the rate will not vitiate the result if the star passes near the zenith.

This method is simple in application and admits of a high

degree of precision. But it is obvious that though difficulties of refraction are absent errors in declination enter into the final determination. This is the more important since the number of stars passing near the zenith in any locality is limited and it may be difficult to find enough with well determined declinations to supply a working list.

There remain to be discussed two methods of a high degree of precision. The first of these differs from the ones so far discussed in being practically independent of the declination. The second is largely independent of errors in refraction and has certain practical advantages over the prime vertical method.

If the altitude of a circum-polar star is measured at its upper culmination, S_N, and again at its lower culmination, S_N', it is apparent that the mean of these altitudes is the altitude of the pole, P, i.e. the latitude of the place. As stated above the great advantage of this method is that it is largely free from errors in the declination of the star, and is therefore from this standpoint independent of the work of other observers. In very accurate work the slight change in altitude due to precession and nutation over a period of twelve hours would be introduced. But any error in the declination used in this calculation would not appreciably affect these minute corrections. Aside from the disadvantages and difficulties in the actual observations, the objection to this method is that any error in refraction is present in the final result. This frequently becomes a serious obstacle to its use, especially in low lat-

itudes. A variation of this method for places near the equator is found in the determination of the latitude by means of the meridian zenith distances of the sun at the summer and the winter solstices. If ζ and ζ' are the two zenith distances and ε the obliquity of the ecliptic, for the summer solstice we have $\phi = \zeta + \varepsilon$, and for the winter solstice $\phi = \zeta' - \varepsilon$

$$\therefore \phi = \tfrac{1}{2}(\zeta + \zeta').$$

There are practical objections to a method of determination extending over such a period of time, such for instance as the variation in ε. As the sun will not as a rule be in the meridian at the solstice, it is usually necessary to reduce its altitude to that position. It is obvious that the sun at the time of any particular solstice can be observed at but a limited number of places. The main theoretic difficulty with the method is the matter of refraction mentioned above.

The errors in refraction may be reduced to a value that is practically negligible in the Zenith Telescope method, the essential features of which are due to Captain Andrew Talcott of the United States Corps of Engineers. Though errors of declination affect the results, the list of available stars for any one locality is large, and by careful selection this difficulty may to some extent be overcome. This becomes increasingly true as new and carefully corrected star lists are added to those already extant. The advantages already noted together with others to be pointed out in the detailed discussion of the method which follows, unite to make this method the most accurate as yet

devised. Chauvenet says of it, (Spherical and Practical Astronomy, Volume II, page 340.), "The method of finding the latitude by this instrument, now known as Talcott's method, is one of the most valuable improvements in practical astronomy of recent years, surpassing all previous methods (not excepting that of Bessel by prime vertical transits) both in simplicity and accuracy."

In this method use is made of two stars, S_S and S_N, one of which crosses the meridian north of the zenith and the other south of it. If δ_N, δ_S, ζ_N, and ζ_S are the declinations and true zenith distances of the north and south stars respectively, formula (1) becomes;

$$\phi = \tfrac{1}{2}(\delta_S + \delta_N) + \tfrac{1}{2}(\zeta_S - \zeta_N) \qquad (2)$$

The zenith distances of the two stars should be about equal for two important reasons; first, the correction for refraction will then be a differential correction and hence very small, second, the difference in the observed zenith distances may then be made to depend on filar-micrometer readings. The vertical circle of the zenith telescope is thus used simply as a finder in order to bring the micrometer into position for observing the stars. Any change which may take place in the position of the vertical circle during the observation, (in particular when the position of the instrument is changed between the transits of the two stars), is recorded by a level bubble both ends of which are read as near the time of transit as possible. The formula with the micrometer, refraction and level terms is as follows;

$$\phi = \tfrac{1}{2}(\delta_S + \delta_N) + \tfrac{r}{2}(M_S - M_N) + \tfrac{d}{4}\left[(n_S + n_N) - (s_S + s_N)\right] + \tfrac{1}{2}(R_S - R_N) \qquad (3)$$

where;

r is the value of one turn of the micrometer head.

M_S and M_N are the micrometer readings on the south and north stars respectively.

d is the value of one division of the level bubble.

n_S and s_S are the north and south level readings for the south star.

n_N and s_N are the north and south level readings for the north star.

$(R_S - R_N)$ is the differential refraction. #

In the latitude determination which follows it will be seen, (Section V), that the attempt has been made to overcome in so far as possible the main objection to the method by consulting various reliable sources as to the declinations involved.

#Another term must be added to this formula to make it applicable to cases where the zenith distance is measured when the star is near but not on the meridian. No such observations are considered in this paper and hence the term is omitted.

SECTION II.

The Instrument.

Preliminary Work.

The Zenith Telescope of the Astronomical Laboratory of Harvard College is of three inch aperture and is mounted on two granite pillars. The filar-micrometer is of the usual form. On either side of the meridian wire there are wires parallel to it. There are five movable, i. e. horizontal wires governed by the micrometer screw. The field is illuminated by small electric bulbs in the ends of the horizontal axis, the amount of illumination being governed by the turning of a mirror. During the work here described a single level bubble was used. The necessary instrumental constants were supplied by the Director of the Laboratory, (See Table I), whose statement was also accepted as to the adjustment of the instrument.

From the "Catalogue of the Mean Declination of 2018 Stars for January 1, 1875", T. H. Safford, and the "Sternverzeichnis -- -- für das Jahr 1900.0", J. and R. Ambronn, thirty-eight stars were selected for use in this work. Two of these stars were later rejected as they were too near the sun for observation. The thirty-six remaining stars gave twenty-two pairs, as one group of three stars gave two pairs and another group of five gave six pairs.

In order that both stars of a pair might be observed in the field of the micrometer with the same vertical circle reading, care was taken to select pairs in which the difference of the

TABLE I.

Constants used for reducing observations.

One revolution of the micrometer head equals, 55".115 #

One division of the level bubble equals, 1".554 #

Wire Intervals.

III to I,	-19.567 Revolutions.	
III to II,	- 9.880	"
III to IV,	+ 9.780	"
III to V,	+19.656	"

The constants given above were supplied by the Director of the Laboratory.

Tables of decimal parts were constructed for purposes of reduction.

Differential Refraction.

(See Hayford's Geodetic Astronomy Art. 304.)

Pair	$\frac{1}{2}(R_S-R_N)$	Pair	$\frac{1}{2}(R_S-R_N)$	Pair	$\frac{1}{2}(R_S-R_N)$
II	+.18	IX_2	+.03	XVI_2	-.03
III	+.10	X	+.09	XVI_3	-.17
IV	+.23	XI	-.10	XVI_4	-.08
V	+.13	XII	+.05	XVI_5	-.05
VI	-.02	XIII	+.02	XVI_6	+.04
VII	+.02	XIV	-.03	XVII	-.06
VIII	-.05	XV	-.18		
IX_1	+.15	XVI_1	-.12		

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zenith distances did not greatly exceed 20', an approximate value of ϕ being assumed for this work. The difference in the right ascensions for the two stars of a pair was in most cases not less than two minutes of time. It was thus possible to complete the readings accurately. At the same time no interval was of sufficient length to introduce too large a chance of error from outside causes acting on the instrument. The stars were mainly of the fourth, fifth, and sixth magnitudes, the total range according to the Safford Catalogue being from 2.3 to 6.5.

Following the selection of the list, the mean places of the stars were reduced to 1909.0. As the epoch of the Safford Catalogue is 1875.0, the precession of α and of δ for the middle epoch was determined in each case from;

$$\frac{d\alpha}{dt} = m + n \sin\alpha \tan\delta. \tag{4}$$

$$\frac{d\delta}{dt} = n \cos\alpha \tag{5}$$

The α and δ of (4) and (5) were determined for the middle epoch 1892, by using the precession for 1875 as given in the catalogue. The value of m used was $46''.088$ and the value of the logarithm of n used was 1.302174. In cases where the proper motion was known that correction was of course made first. As an illustration of the method the reduction of Safford 764 is given on the following page. As the epoch of the Ambronn catalogue is 1900.0 the yearly variation as given in the catalogue was used directly for bringing the position to 1909.0. When this work had been completed the zenith distance for each star and the vertical circle settings for each pair were determined.

Reduction of the mean place of Safford 764 to 1909.0.

(See preceding page.)

α	δ	α	δ
α_{75}	δ_{75}	$18^h\ 15^m\ 28.88^s$	$36°\ 00'\ 33.''2$
μ	μ	$+0.001^s$	$+0.023''$
34μ	34μ	$+.034^s$	$+.782''$
$\alpha_{75}+34\mu$	$\delta_{75}+34\mu$	18 15 28.91	36 00 34.0
Annual Precession		$+2.162^s$	$+1.35''$
17 Ann. Preces.		+35.734	+22.95
α_{92} (time)		18 16 4.64	
α_{92} (arc)	δ_{92}	$274°\ 1'\ 9.''60$	$36°\ 00'\ 57.''0$
log n	log n + log 34	1.302174	2.833653
$l \sin \alpha_{92}$	$l \cos \alpha_{92}$	9.998930 (n)	8.845675
$l \tan \delta_{92}$		9.861514	
Sum of logs		1.162618 (n)	1.679328
Number		$-14.'542$	
m		+46.088	
$\frac{d\alpha}{dt}$ (arc)		$+31.''546$	
$\frac{d\alpha}{dt}$ (time)		$+2.^s103$	
$34\frac{d\alpha}{dt}$	$34\frac{d\delta}{dt}$	$+1^m\ 11.^s50$	$+47.''789$
α_{09}	δ_{09}	$18^h\ 16^m\ 40.^s41$	$36°\ 1'\ 21.''8$

TABLE II.

This table is a copy of the Observatory working-list compiled from the data determined as described in the preceding page. The columns in order from the left give; 1) the pair, 2) the Safford or Ambronn star number, 3) the magnitude, 4) α(1909.0), 5) δ(1909.0), 6) and 7) the zenith distance north or south, 8) the vertical circle setting.

Pair.	Number	M	α (1909.0) h	m	s	δ (1909.0) °	′	″	Z. D. °	′	″	N.S.	Setting. °	′
I	(Safford) 328	6.	14	44	21.8	24	44	36.8	17	38	1.2	S	17	27
	338	6.5	14	49	7.68	59	39	50.1	17	17	12.1	N		
II	362	5.	15	3	40.36	54	54	22.3	12	31	44.3	N	12	42
	372	5.	15	10	40.69	29	30	6.0	12	52	32.0	S		
III	382	6.	15	17	11.2	25	17	11.2	17	5	26.8	S	17	0
	400	3.	15	21	24.02	59	17	4.3	16	54	26.3	N		
IV	415	4.	15	29	15.42	31	39	58.3	10	42	39.7	S	10	30
	444	6.5	15	40	21.96	52	38	51.3	10	16	13.3	N		
V	470	6.	15	52	28.97	38	12	33.4	4	10	4.6	S	4	2
	484	5.4	15	59	57.74	46	17	19.1	3	54	41.1	N		
VI	509	6.5	16	13	7.19	29	22	29.2	13	0	8.8	S	13	1
	529	6.5	16	22	25.98	55	24	40.8	13	2	2.8	N		
VII	537	4.9 / 8 / 6.2	16	25	39.29	42	4	55.9	0	17	42.1	S	0	16
	552	4.5	16	31	10.18	42	37	27.2	0	14	49.2	N		
VIII	558	5.3	16	34	2.12	53	4	57.3	10	42	19.3	N	10	40
	567	3.2	16	37	51.54	31	45	50.3	10	36	47.7	S		
IX	(Ambronn) 5328	6.1	16	44	25.1	42	24	4.3	0	1	26.3	N	0	12
	5345	6.5	16	47	41.4	42	2	54.8	0	19	43.2	S		
	5385	6.5	16	54	58.2	42	39	11.2	0	16	33.2	N		
X	(Safford) 619	6.	17	2	18.55	43	56	7.7	1	33	29.7	N	1	39
	626	6.	17	4	48.68	40	38	5.1	1	44	32.9	S		
XI	652	5.6	17	17	15.26	32	35	4.0	9	47	34.0	S	9	54
	673	3.2	17	28	22.53	52	22	6.1	9	59	28.1	N		
XII	701	3.4	17	42	53.77	27	46	24.2	14	36	13.8	S	14	34
	719	3.4	17	51	57.40	56	53	11.7	14	30	33.7	N		
XIII	722	2.3	17	54	29.69	51	29	56.9	9	7	18.9	N	9	9
	727	6.5	17	57	16.70	33	13	0.5	9	9	37.5	S		
XIV	737	5	18	3	34.25	30	32	54.2	11	49	43.8	S	11	52
	750	6	18	8	39.76	54	15	31.5	11	52	53.5	N		
XV	764	5.4	18	16	40.41	36	1	21.8	6	21	16.2	S	6	32
	774	5	18	19	13.10	49	4	32.0	6	41	54.0	N		
XVI	796	5.6	18	31	52.79	52	16	51.5	9	54	13.5	N	9	45
	811	6	18	37	47.32	52	6	35.9	9	43	57.9	N		
	832	6.3	18	46	22.66	32	42	26.8	9	40	11.2	S		
	852	6.	18	53	36.87	32	47	1.4	9	35	36.6	S		
	856	3.4	18	55	32.47	32	33	51.9	9	48	46.1	S		
XVII	873	6	19	1	29.63	31	36	32.0	10	46	6.0	S	10	49
	879	6	19	2	52.38	53	15	23.1	10	52	45.1	N		

It was also necessary to determine the apparent declinations for the stars at the times of the various observations for use in the reductions with formula (3). In order that the work of reduction might be carried along during the period of observation as a check on the work, an ephemeris with five day intervals was prepared of apparent declinations for the period of observation. The Independent Star Numbers were used, the formula for the declination being as follows; (See Chauvenet, Vol. I, p 650).

$$\delta' = \delta + i \cos\delta + \tau\mu + g \cos(G+\alpha) + h \cos(H+\alpha) \sin\delta.$$

An illustration of the method of reduction to apparent place follows;

Reduction of Safford 764 to apparent place for

August 11, 1909.

δ				$36^\circ\ 1'\ 21.''8$	δ
α	274°	$10'$	$6.''15$		
μ			$+0.023$		
$\tau\mu$				$+0.014$	$\tau\mu$
$\log \cos\delta$		9.9078			
$\log i$		0.7876			
		0.6954		$+4.959$	$i\cos\delta$
G	336	23	36.		
$G+\alpha$	610	33	42.		
$\log \cos(G+\alpha)$		9.52217 (n)			
$\log g$		0.83062			
		0.35279 (n)		-2.253	$g\cos(G+\alpha)$
H	133	37	30		
$H+\alpha$	407	47	36.		
$\log h$		1.29070			
$\log \cos(H+\alpha)$		9.82724			
$\log \sin\delta$		9.76946			
		0.88740		$+7.716$	$h\cos(H+\alpha)\sin\delta$
				$36^\circ\ 1'\ 32.''2$	δ'

The values of $\frac{1}{2}(\delta_S+\delta_N)$ were determined for the various pairs on the dates of the ephemeris. As the intervals were short it was assumed in the interpolation that the variation of $\frac{1}{2}(\delta_S+\delta_N)$ was uniform. Table III is a copy of the ephemeris.

TABLE III.

Apparent Declination.

$\frac{1}{2}(\delta_S+\delta_N)$

	July 7 (19hr)	July 12	July 17	July 22 (20hr)	July 27	August 1	August 6 (21hr)	August 11	August 16
	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
I 328 (Saf.)	24 44 42.0	42.6	43.0						
I 338	59 40 2.4	3.1	3.4						
$\frac{1}{2}(\delta_s+\delta_N)$	42 12 22.2	22.85	23.2						
II 362	54 54 33.4	34.2	34.6						
II 372	29 30 12.0	12.8	13.2						
$\frac{1}{2}(\delta_s+\delta_N)$	42 12 22.7	23.5	23.9						
III 382	25 17 16.1	16.8	17.3						
III 400	59 17 15.4	16.3	16.8						
$\frac{1}{2}(\delta_s+\delta_N)$	42 17 15.75	16.55	17.05						
IV 415	31 40 4.4	5.3	5.9	6.4					
IV 444	52 39 0.8	1.8	2.5	3.1					
$\frac{1}{2}(\delta_s+\delta_N)$	42 9 32.6	33.55	34.2	34.75					
V 470	38 12 40.3	41.3	42.0	42.6	43.4	43.76	44.12		
V 484	46 17 27.0	28.1	28.9	29.5	30.33	30.75	31.14		
$\frac{1}{2}(\delta_s+\delta_N)$	42 15 3.65	4.7	5.45	6.05	6.87	7.26	7.63		
VI 509	29 22 33.9	34.9	35.7	36.3	37.1	37.56	37.99	38.48	
VI 529	55 24 48.9	50.1	51.1	51.9	52.8	53.37	53.87	54.42	
$\frac{1}{2}(\delta_s+\delta_N)$	42 23 41.4	42.5	43.4	44.1	44.95	45.46	45.93	46.45	
VII 537	42 5 2.4	3.5	4.4	5.2	6.1	6.71	7.22	7.8	
VII 552	42 37 33.5	34.7	35.7	36.5	37.4	38.03	38.57	39.19	
$\frac{1}{2}(\delta_s+\delta_N)$	42 21 17.95	19.1	20.05	20.85	21.75	22.37	22.90	23.50	
VIII 558	53 5 4.7	6.0	7.0	7.8	8.8	9.5	10.03	10.67	
VIII 567	31 45 54.9	56.0	56.9	57.6	58.6	59.1	59.66	46 0.28	
$\frac{1}{2}(\delta_s+\delta_N)$	42 25 29.8	31.0	31.95	32.7	33.7	34.3	34.84	35.48	
IX 5328 (Ambr.)	42 24 10.1	11.4	12.4	13.2	14.2	14.9	15.5	16.2	16.5
IX 5345	42 3 0.5	1.7	2.7	3.6	4.6	5.3	5.9	6.7	7.0
IX $\frac{1}{2}(\delta_s+\delta_N)$	42 13 35.3	36.55	37.55	38.4	39.4	40.1	40.7	41.45	41.75
IX 5385	42 39 16.7	17.9	19.0	19.9	21.0	21.7	22.4	23.1	23.5
$\frac{1}{2}(\delta_s+\delta_N)$	42 21 8.6	9.8	10.85	11.6	12.8	13.5	14.5	14.9	15.25
X 619 (Saf.)	43 56 13.0	14.3	15.4	16.4	17.5	18.3	18.97	19.77	20.17
X 626	40 38 10.0	11.3	12.4	13.3	14.4	15.2	15.86	16.67	17.07
$\frac{1}{2}(\delta_s+\delta_N)$			42 17 13.9	14.85	15.95	16.75	17.42	18.22	18.62

	July 7 (19 hrs)	July 12	July 17	July 22 (20 hrs)	July 27	August 1	August 6 (21 hrs)	August 11	August 16
(Safford)	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
XI 652	32° 35′ 7.1″	8.3	9.4	10.3	11.3	12.1	12.74	13.55	13.95
673	62 22 10.9	12.4	13.7	14.7	16.0	17.0	17.87	18.86	19.44
$\frac{1}{2}(\delta_s+\delta_N)$			42 28 41.55	42.5	43.65	44.55	45.30	46.20	46.70
XII 701		27 46 27.6	28.7	29.5	30.6	31.5	32.2	33.0	33.6
719		56 53 17.0	18.5	19.7	21.1	22.2	23.2	24.0	25.1
$\frac{1}{2}(\delta_s+\delta_N)$			42 19 53.6	54.6	55.85	56.85	57.7	58.5	59.35
XIII 722		51 30 2.2	3.24	4.95	6.0	7.36	8.46	9.44	10.34
727		33 13 4.4	5.6	6.6	7.9	8.8	9.7	10.7	11.3
$\frac{1}{2}(\delta_s+\delta_N)$			42 21 34.42	35.78	36.95	38.08	39.08	40.07	40.82
XIV 737		30 32 57.8	59.0	33 0.0	1.2	2.2	3.0	4.0	4.6
750		54 15 36.0	37.5	38.8	40.3	41.5	42.6	43.8	44.6
$\frac{1}{2}(\delta_s+\delta_N)$			42 24 18.25	19.4	20.75	21.85	22.8	23.9	24.6
XV 764		36 1 25.3	26.7	27.8	29.1	30.2	31.1	32.2	33.0
774		49 4 35.8	37.3	38.6	39.5	41.3	42.4	43.7	44.5
$\frac{1}{2}(\delta_s+\delta_N)$			42 33 2.0	3.2	4.3	5.75	6.75	7.85	8.75
XVI 796			52 16 56.31	57.63	59.17	17 0.51	1.66	3.02	3.98
811			52 6 40.45	41.79	43.35	44.72	45.89	47.40	48.27
832			32 42 30.72	31.84	33.19	34.37	35.35	36.56	37.39
(1) $\frac{1}{2}(\delta_s+\delta_N)$			42 29 43.51	44.74	46.18	47.44	48.50	49.79	50.68
(2) $\frac{1}{2}(\delta_s+\delta_N)$			42 24 35.58	36.82	38.27	39.54	40.62	41.98	42.83
852			32 47 5.05	6.20	7.56	8.76	9.76	11.00	11.86
(3) $\frac{1}{2}(\delta_s+\delta_N)$			42 32 0.68	1.92	3.36	4.64	5.71	7.01	7.92
(4) $\frac{1}{2}(\delta_s+\delta_N)$			42 26 52.75	54.00	55.46	56.74	57.82	59.20	60.06
856			32 33 55.60	56.75	58.12	59.33	34 0.33	1.58	2.33
(5) $\frac{1}{2}(\delta_s+\delta_N)$			42 25 25.96	27.19	28.64	29.92	31.00	32.30	33.16
(6) $\frac{1}{2}(\delta_s+\delta_N)$			42 20 18.02	19.27	20.74	22.02	23.11	24.49	25.30
XVII 873				31 36 36.69	38.05	39.27	40.27	41.52	42.39
879				53 15 27.89	29.53	31.02	32.30	33.82	34.95
$\frac{1}{2}(\delta_s+\delta_N)$				42 26 2.29	3.79	5.14	6.28	7.67	8.67

SECTION III.

Observatory Work.

The observations began July, 8, 1909 and ended August 14, 1909. Observations were made on twenty-three different nights there being altogether 467 different observations on stars not including those that were incomplete or led to no result. The work as a rule began a few minutes after sun-set. The chief difficulty encountered in the work of observing was the tremor produced by the city traffic, particularly the heavy electric-cars on Massachusetts Avenue near by. The image was frequently unsteady at the time of transit, the larger component of the oscillations being as a rule parallel to the vertical wire. Occasionally the jar was so heavy as to cause the bubble to run during the observation. When the tremor was so marked as to cause serious doubt as to the value of the observation, a note was of course made on the record. To what extent the size of the probable error of the final result is due to this difficulty it is impossible to tell.

The first six columns of Table IV are copied from the original notes of the observations. The notes themselves will be found at the end of this paper.

TABLE IV.

Observations and Reductions.

Reduction Formula;

$$\phi = \frac{1}{2}(\delta_s + \delta_N) + \frac{n}{2}(M_s - M_N) + \frac{d}{4}\left[(m_s + m_N) - (s_s + s_N)\right] + \frac{1}{2}(R_s - R_N)$$

The columns of the Table from left to right are as follows; 1) the pair, 2) the direction from the zenith, 3) level readings for both ends of the bubble, 4) the micrometer reading, 5) the wire on which the star was at time of transit, 6) date and remarks, 7), 8), 9), and 10), the various terms of the reduction in the order of the formula, (See typical reduction below), 11) the seconds of the reduction, (the degrees and minutes being 42 and 22 respectively in each case.)

Reduction of Pair XI, July 24.

$\frac{1}{2}(\delta_s + \delta_N)$, (See Table III.) = $42^\circ\ 28'\ 42.''96$

$+\frac{n}{2}(M_s - M_N) = \frac{55.''115}{2}\left[21.163 - 24.402 - 9.880\right] =$ $-6\ \ 1.53$

Note; The readings in the micrometer column, (save in one instance, i.e. pair II, July 12), are for the wire on which the transit occurred. These readings differ by exactly ten units from the readings for wire III in the cases of wires II and IV, and by exactly twenty units for wires I and V. In the reduction the readings are first reduced to wire III and the correction for the interval made later.

$+\frac{d}{4}\left[(m_s + m_N) - (s_s + s_N)\right] = \frac{1.554}{4}\left[65.3 - 64.9\right] =$ $+0.155$

$+\frac{1}{2}(R_s - R_N)$ -0.10

$\therefore\ \phi =$ $42^\circ\ 22'\ 41.''48$

Pair	N.S.	Level N.	Level S.	Micrometer	Wire	Date Remarks	$\frac{1}{2}(\delta_S+\delta_N)$ 42° +		$\frac{r}{2}(M_S-M_N)$		Level Correction	Refraction	ϕ 42°22′ +
							′	″	′	″	″	″	″
III	S	16.0	50.9	24.018	III	July 8, 1909							
	N	51.2	17.2	12.274		Poor illumination	17	15.91	+5	23.63	+5.83	+.10	40.22
IV	S	18.3	53.0	32.380	IV	4.018 apparently error for 24.018							
	N	51.5	16.9	3.728	III		9	32.79	+13	3.51	−1.127	+.23	35.40
V	S	18.0	53.2	27.465	IV								
	N	53.0	18.0	10.841	II		15	3.86	+7	28.74	−.078	+.13	32.65
II	N	50.1	18.0	17.288 x	II	July 12, 1909							
	S	18.6	50.4	19.797	IV	*(Readings on wire III)	12	23.5	+10	10.92	−.35	+.18	34.25
III	S	18.4	50.3	24.153	III								
	N	51.5	19.6	12.510		Image unsteady	17	16.55	+5	20.84	+.894	+.10	38.38
V	S	18.7	50.8	27.149	III								
	N	57.0	24.8	10.884			15	4.7	+7	28.22	+4.779	+.13	37.83
VII	S	18.6	51.4	20.385	III								
	N	51.3	18.4	17.460			21	19.1	+1	20.61	−.117	+.02	39.61
VIII	N	44.3	11.4	20.880	III	Bisection rough							
	S	16.8	49.6	14.641		Image unsteady	25	31.0	−2	51.935	−4.157	−.05	34.86
III	S	18.0	47.5	24.220	III	July 14, 1909							
	N	47.7	18.1	12.653			17	16.75	+5	18.765	+.117	+.10	35.72
IV	S	20.3	49.9	32.374	IV								
	N	43.6	14.0	3.630	II		9	33.81	+13	2.74	−4.895	+.23	31.88
V	S	17.0	46.8	27.129	III								
	N	48.5	18.4	10.788			15	5.0	+7	30.315	+1.205	+.13	36.65
VII	S	18.4	49.0	20.3095	III								
	N	51.0	20.2	17.514			21	19.48	+1	17.03	+1.477	+.02	38.01
V	S	18.1	48.4	26.928	III	July 17, 1909							
	N	47.1	16.6	10.592			15	5.45	+7	30.18	−1.088	+.13	34.67
VI	S	13.0	43.8	17.160	III								
	N	47.4	16.3	19.663			23	43.4	−1	8.97	+2.681	−.02	37.09
VII	S	18.1	49.2	20.297	III								
	N	49.2	18.1	17.450			21	20.05	+1	18.455	—	+.02	38.52
VIII	N	49.7	18.6	21.346	III								
	S	19.1	50.3	14.833			25	31.95	−2	59.49	−.428	−.05	31.98
IX	N	49.7	18.2	7.211	II								
	S	16.2	48.0	26.787	III		13	37.55	+8	56.15	+1.438	+.15	35.29
	N	51.3	19.8	23.866	III	Poor bisection	21	10.85	+1	20.495	+2.681	+.03	34.06
XI	S	16.7	48.8	11.237	III								
	N	50.6	18.0	24.456			28	41.55	−6	42.85	+1.205	−.10	38.46
XII	S	16.5	49.1	20.484	III								
	N	51.0	18.0	14.582			19	53.6	+2	42.64	+1.321	+.05	37.61
XIII	N	49.2	16.4	16.845	III								
	S	16.8	49.7	19.186			21	34.42	+1	4.505	−.35	+.02	38.60

Pair	N.S	Level N	Level S	Micr.	Wire	Date Remarks	$\frac{1}{2}(\delta_S+\delta_N)$ ′	″	$\frac{r}{2}(M_S-M_N)$ ′	″	Level Cor. ″	Ref. ″	ϕ ″
XIV	S	18.8	51.6	15.847	III		24	18.25	-1	40.62	+.117	-.03	37.72
	N	51.8	18.7	19.505									
XV	S	15.9	48.8	6.535	II		33	2.0	-10	17.585	-3.885	-.18	40.35
	N	44.0	10.7	29.286	IV								
IV	S	11.4	46.3	32.204	IV	July 19, 1909	9	34.42	+12	53.87	+3.730	+.23	32.25
	N	51.3	16.0	3.782	II	Rough bisection							
V	S	13.0	48.5	26.965	III		15	5.69	+7	26.02	+4.274	+.13	36.11
	N	54.1	18.4	10.780									
VI	S	15.8	51.6	17.101	III		23	43.68	-1	7.48	+1.865	-.02	38.04
	N	54.2	18.0	19.550									
VII	S	15.2	51.2	20.154	III		21	20.43	+1	16.65	+1.088	+.02	38.19
	N	52.6	16.6	17.372									
VIII	N	56.3	20.2	21.130	III		25	32.25	-3	2.49	+1.554	-.05	31.26
	S	18.2	54.3	14.508									
IX	N	50.0	14.0	7.113	II		13	37.89	+8	55.71	—	+.15	33.75
	S	14.0	50.0	26.673	III								
IV	S	13.0	49.0	32.010	IV	July 21, 1909	9	34.64	+12	55.06	+2.835	+.23	32.76
	N	52.7	16.6	3.545	II								
V	S	13.0	49.4	26.823	III	Image unsteady	15	5.93	+7	33.70	-1.748	+.13	38.01
	N	47.1	10.8	10.359									
VI	S	15.8	52.5	17.294	III		23	43.96	-1	11.53	+1.560	-.02	33.97
	N	54.5	17.7	19.890		Image unsteady							
VII	S	16.8	53.7	20.186	III		21	20.69	+1	20.20	-.661	+.02	40.25
	N	52.8	16.0	17.276		Image unsteady							
VIII	N	55.4	18.5	21.209	III		25	32.55	-3	1.00	+.855	-.05	32.36
	S	17.4	54.3	14.641									
IX	N	50.0	13.0	7.130	II								
	S	17.5	54.4	26.861	III		13	38.23	+9	0.425	-3.458	+.15	35.35
	N	50.1	13.0	23.522	III		21	11.45	+1	32.015	-3.419	+.03	40.08
X	N	48.9*	16.9	12.604	III	* apparently an error for 53.9	17	14.66	+5	29.83	-1.321	+.09	43.26
	S	18.6	55.6	24.573	IV								
XI	S	16.8	54.4	11.140	III		28	42.31	-6	4.23	-.117	-.10	37.86
	N	54.3	16.6	24.357									
XII	S	18.2	56.3	20.535	III		19	54.4	+2	44.96	-1.360	+.05	38.05
	N	54.5	16.5	14.549		Image unsteady							
XIII	N	54.5	16.5	16.744	III		21	35.504	+1	0.65	-1.251	+.02	35.12
	S	18.1	56.3	18.945									
XIV	S	16.4	54.4	15.805	III		24	19.17	-1	41.07	-.233	-.03	37.84
	N	54.2	16.0	19.473									
XV	S	16.0	54.0	6.538	II		33	2.96	-10	20.785	+.194	-.18	42.19
	N	54.3	16.2	29.405	IV								

Pair	N.S.	Level N	Level S	Micr.	Wire	Date Remark	$\frac{1}{2}(\delta_S+\delta_N)$		$\frac{r}{2}(M_S-M_N)$		Level Cor.	Ref.	ϕ
							′	″	′	″	″	″	″
	N	56.7	18.5	28.501	IV								
	N	54.5	16.4	17.131	III								
XVI	S	13.0	51.2	12.651	III	Rough bisection	29	44.49	−7	10.73	+4.274	−.12	37.91
							24	36.57	−2	3.45	+2.603	−.03	35.69
	S	16.0	54.3	7.756	III		32	1.67	−9	25.63	+1.924	−.17	37.79
							26	53.75	−4	18.355	+.233	−.08	35.55
	S	16.0	54.3	22.310	IV		25	26.94	−2	50.615	+1.924	−.05	38.20
							20	19.02	+2	16.665	+.233	+.04	35.96
V	S	17.0	54.0	26.946	III	July 22, 1909	15	6.05	+7	30.95	+.894	+.13	38.02
	N	55.3	18.0	10.582									
VI	S	16.9	54.5	17.546	III		23	44.1	−1	8.50	+.117	−.02	35.70
	N	54.7	16.8	20.032									
VII	S	16.8	54.2	20.280	III		21	20.85	+1	17.22	+.855	+.02	38.94
	N	55.4	17.8	17.478		Image unsteady							
VIII	N	54.4	16.8	21.316		Rough bisection	25	32.7	−3	0.62	+.039	−.05	32.07
	S	16.8	54.3	14.762	III								
	N	54.4	16.7	7.142	II								
IX	S	16.8	54.5	26.802	III		13	38.4	+8	58.47	−.078	+.15	36.94
	N	54.6	16.8	23.689	III		21	11.6	+1	25.79	+.039	+.03	37.46
X	N	54.4	16.5	12.610	III		17	14.85	+5	25.67	−2.759	+.09	37.85
	S	20.0	58.0	24.428									
XI	S	12.0	50.8	10.989	III		28	42.5	−6	4.725	+0.155	−.10	37.83
	N	51.0	12.2	24.224									
XII	S	15.7	54.6	20.472	III		19	54.6	+2	48.83	−4.079	+.05	39.40
	N	49.3	10.5	14.346									
XIII	N	57.0	18.1	16.767	III		21	35.775	+0	58.065	+4.002	+.02	37.86
	S	13.0	51.8	18.874									
XIV	S	15.4	54.4	15.513	III		24	19.4	−1	44.41	+2.059	−.03	37.02
	N	57.0	18.1	19.302									
XV	S	12.7	51.9	6.324	II		33	3.2	−10	24.33	+3.963	−.18	42.65
	N	56.8	18.0	29.320	IV	Bisection rough.							
	N	54.5	15.6	28.619	IV								
	N	54.5	15.8	17.291	III								
XVI	S	15.5	54.5	12.916	III		29	44.74	−7	6.675	+.039	−.12	37.98
							24	36.82	−2	0.565	+.117	−.03	36.34
	S	16.2	54.5	7.889	III		32	1.92	−9	25.22	+.155	−.17	36.68
							26	54.0	−4	19.10	+.233	−.08	35.05
	S	15.2	54.5	22.400	IV	Rough bisection	25	27.19	−2	51.385	+.155	−.05	35.91
							20	19.27	+2	14.73	+.233	+.04	34.27
V	S	18.0	53.4	27.083	III	July 24, 1909	15	6.376	+7	27.48	−3.07	+.13	30.91
	N	49.5	14.0	10.725	II								

VI
II
III
I
X
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I
II
VI
III
I

Pair	N.S.	Level N	Level S	Micr.	Wire	Date Remarks	$\frac{1}{2}(\delta_s+\delta_N)$ '	"	$\frac{n}{2}(M_s-M_N)$ '	"	Level Corr. "	Ref. "	ϕ "
VI	S	16.7	51.3	17.150	III								
	N	54.6	18.8	19.882		Very rough bisection Clouds!	23	44.44	-1	15.28	+2.486	-.02	31.63
VII	S	18.2	54.0	20.141	III								
	N	54.2	18.2	17.394			21	21.21	+1	15.695	+0.078	+.02	37.00
VIII	N	54.0	18.0	21.288	III								
	S	15.8	52.0	14.659			25	33.1	-3	2.68	+1.632	-.05	32.00
IX	N	51.8	15.6	7.059	II								
	S	16.0	52.3	26.614	III		13	38.8	+8	55.575	-0.35	+.15	34.18
	N	53.2	16.6	23.545	III		21	12.08	+1	24.57	+0.583	+.03	37.26
X	N	53.3	16.6	12.867	III								
	S	14.7	51.3	24.676	IV		17	15.29	+5	19.36	+1.516	+.09	36.26
XI	S	13.9	51.0	11.163	II								
	N	51.3	14.0	24.402	III		28	42.96	-6	1.535	+0.155	-.10	41.48
XII	S	13.0	50.4	20.465	III	Image unsteady							
	N	54.2	16.8	14.672			19	55.1	+2	39.64	+2.953	+.05	37.74
XIII	N	51.9	14.2	16.987	III								
	S	16.6	54.3	19.248			21	36.245	+1	2.30	-1.865	+.02	36.70
XIV	S	15.7	53.5	15.613	III	Image unsteady							
	N	54.6	16.7	19.388			24	19.94	-1	44.025	+.816	-.03	36.70
XV	S	15.6	53.7	6.631	II								
	N	54.0	16.0	29.544	IV		33	3.64	-10	22.05	+.272	-.18	41.59
XVI	N	54.4	16.3	28.715	IV								
	N	54.4	16.2	17.443	III								
							29	45.316	-7	2.44	+.117	-.12	42.87
	S	16.0	54.4	13.046	II								
							24	37.40	-1	57.86	+.078	-.03	39.59
							32	2.498	-9	21.03	+.155	-.17	41.45
	S	16.0	54.3	8.017	II								
							26	54.582	-4	16.46	+.117	-.08	38.16
							25	27.772	-2	47.91	+.155	-.05	39.97
	S	16.0	54.3	22.402	III	Image unsteady							
							20	19.856	+2	16.665	+.117	+.04	36.68
V	S	14.0	46.5	26.974	III	July 26, 1909 Bisection rough							
	N	46.7	14.0	10.734	II		15	6.702	+7	24.23	+.039	+.13	31.10
VI	S	16.0	48.8	17.360	III								
	N	51.3	18.0	19.845			23	44.78	-1	8.47	+1.748	-.02	38.04
VII	S	16.8	49.8	20.117	III								
	N	49.7	16.2	17.285			21	21.57	+1	18.04	-.272	+.02	39.36
VIII	N	51.2	18.0	21.120	III								
	S	16.7	50.0	14.503			25	33.5	-3	2.35	+.971	-.05	32.07
IX	N	48.7	14.8	7.066	II								
	S	16.8	50.6	26.674	III		13	39.2	+8	57.03	-1.516	+.15	34.86
	N	50.0	15.8	23.527	III		21	12.56	+1	26.725	-.622	+.03	38.69

Pair	N.S.	Level N	Level S	Microm.	Wire	Date Remarks	½(δs+δN) ′	″	r/2(Ms−MN) ′	″	Level ″	Ref. ″	φ ″
X	N	50.8	16.7	12.708	II								
	S	12.3	46.5	24.311	III	Image unsteady	17	15.73	+5	16.435	+3.380	+.09	35.64
XI	S	15.9	50.6	11.124	II								
	N	50.8	15.8	24.433	III		28	43.42	−6	3.46	+.117	−.10	39.98
XII	S	16.8	51.8	20.617	III	Image unsteady							
	N	53.6	18.0	14.722			19	55.6	+2	42.445	+1.166	+.05	39.26
XIII	N	51.3	15.8	16.713	III								
	S	18.0	54.7	19.028			21	36.715	+1	3.795	−2.176	+.02	38.35
XIV	S	16.3	51.8	15.777	III								
	N	52.2	16.6	19.526			24	20.48	−1	43.31	+.272	−.03	37.41
XV	S	16.9	52.4	6.510	II								
	N	58.8	22.8	29.558	IV	Rough bisection	33	4.08	−10	25.77	+4.779	−.18	42.91
XVI	N	52.8	16.8	28.656	IV								
	N	51.8	16.0	17.352	III								
	S	15.8	51.8	12.895	II		29	45.892	−7	4.97	+.727	−.12	41.58
							24	37.98	−1	59.52	+.078	−.03	38.51
	S	15.8	51.8	7.870	II		32	3.076	−9	23.45	+.777	−.17	40.23
							26	55.164	−4	17.99	+.078	−.08	37.17
	S	14.3	50.3	22.271	III		25	28.354	−2	49.90	+1.943	−.05	40.35
							20	20.442	+2	15.565	+1.243	+.04	37.29
XVII	S	15.0	51.2	15.112	III								
	N	53.0	16.8	22.779	IV	Rough bisection	26	3.49	−3	25.225	+1.339	−.06	89.60
VI	S	16.8	49.8	17.175	III	July 27, 1909							
	N	50.0	16.7	19.664			23	44.95	−1	8.58	+.117	−.02	36.47
VII	S	18.2	51.4	20.161	III								
	N	51.2	17.8	17.387			21	21.75	+1	16.44	−.233	+.02	37.98
VIII	N	51.2	17.8	21.015	III								
	S	16.8	50.1	14.382			25	33.7	−3	2.79	+.816	−.05	31.68
IX	N	50.2	16.8	7.170	II								
	S	15.8	49.7	26.613	III		13	39.4	+8	52.49	+.583	+.15	32.62
	N	49.7	15.8	23.482	III		21	12.8	+1	26.285		+.03	39.12
X	N	49.9	16.0	12.744	II	Light clouds							
	S	15.8	49.7	24.400	III		17	15.95	+5	17.90	+.155	+.09	34.10
XI	S	16.1	50.2	11.078	II								
	N	49.6	15.6	24.346	III		28	43.65	−6	2.33	−.428	−.10	40.79
XII	S	16.4	51.3	20.431	III								
	N	51.7	16.8	14.605			19	55.85	+2	40.55	+.311	+.05	36.76
XIII	N	50.8	16.0	16.741	III	Before observation							
	S	19.5	54.5	19.132		level stood 16.3 51.3	21	36.95	+1	5.885	−2.797	+.02	40.06
XIV	S	15.8	50.7	15.567	III								
	N	51.3	16.3	19.449			24	20.75	−1	46.97	+.428	−.03	34.21

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XII

XI

XII

Pair.	N.S.	Level N.	Level S.	Microm.	Wire.	Date Remarks	$\frac{1}{2}(\delta_s + \delta_N)$ '	"	$\frac{n}{2}(M_s - M_n)$ '	"	Level "	Ref. "	ϕ "
XV	S	14.0	49.0	6.520	II								
	N	49.0	14.0	29.448	IV		33	4.3	−10	22.46	—	−.18	41.66
	N	51.0	15.8	28.489	IV								
	N	49.2	14.0	17.173	III								
XVI	S	16.0	51.3	12.853	III		29	46.18	−7	4.83	−.194	−.12	41.04
							24	38.27	−1	59.05	−1.593	−.03	37.60
	S	16.0	51.3	7.848	II		32	3.365	−9	19.455	−.194	−.17	43.55
							26	55.455	−4	13.67	−1.593	−.08	40.112
	S	16.0	51.3	22.244	III		25	28.645	−2	46.04	−.194	−.05	42,36
							20	20.735	+2	19.745	−1.593	+.04	38.93
XVII	S	15.7	51.2	15.207	III								
	N	52.3	16.7	22.738	IV	Image unsteady	26	3.79	−3	21.485	+.816	−.06	43.06
VI	S	16.7	49.2	17.196	III	July 28, 1909							
	N	48.7	15.8	19.599			23	45.053	−1	6.215	−.544	−.02	38.27
VII	S	16.8	49.7	20.188	III								
	N	49.9	16.7	17.412		Rough bisection	21	21.874	+1	16.49	+.117	+.02	38.48
VIII	N	47.5	14.2	21.329	III								
	S	14.0	47.5	14.722			25	33.82	−3	2.075	+.078	−.05	31.77
IX	N	49.6	16.0	7.306	II								
	S	18.3	51.7	26.921	III		13	39.54	+8	57.225	−1.709	+.15	35.21
	N	48.8	16.1	23.711	III		21	12.94	+1	28.46	−1.982	+.03	39.45
X	N	49.2	15.7	21.630	III	Bisection rough. Setting 1° 31'. S level reading estimated from bubble length.							
	S	31.1	64.6	33.922	IV		17	16.11	+5	32.67	−11.966	+.09	36.90
XI	S	14.0	48.2	10.759	II								
	N	50.2	15.7	24.070	III		28	43.83	−6	3.515	+1.438	−.10	41.65
XII	S	15.8	50.3	20.576	III								
	N	50.8	16.0	14.782			19	56.05	+2	39.67	+.272	+.05	36.04
XIII	N	49.3	15.7	16.794	III								
	S	16.0	49.6	18.977			21	37.176	+1	0.15	−.233	+.02	37.11
XIV	S	16.0	50.8	15.235	III								
	N	51.3	16.3	19.020			24	20.97	−1	44.30	+.311	−.03	36.95
XV	S	15.8	50.8	6.598	II								
	N	51.2	16.0	29.567	IV		33	4.59	−10	23.59	+.233	−.18	41.05
	N	51.1	15.8	28.627	IV								
	N	51.8	16.0	17.317	III								
XVI	S	15.4	51.2	12.890	II		29	46.432	−7	4.31	+.194	−.12	42.20
							24	38.525	−1	58.695	+.466	−.03	40.30
	S	15.3	51.2	7.865	II		32	3.619	−9	22.79	+.233	−.17	40.89
							26	55.712	−4	17.17	+.505	−.08	39.00
	S	15.2	51.1	22.259	III		25	28.90	−2	49.43	+.233	−.05	39.65
							20	20.993	+2	16.19	+.583	+.04	37.81

Pair	N.S.	Level N.	Level S.	Microm.	Wire	Date Remarks	$\frac{1}{2}(\delta_S+\delta_N)$	$\frac{n}{2}(M_S-M_N)$	Level	Ref.	ϕ
							' "	' "	"	"	"
XVII	S	15.0	51.2	15.328	III						
	N	49.2	14.0	22.694			26 4.061	-3 23.00	-1.166	-.06	39.84
VIII	N	50.0	18.2	21.103	III	July 29, 1909					
	S	18.2	50.2	14.486			25 33.94	-3 2.35	-.078	-.05	31.46
X	N	49.6	15.8	12.461	II	Brackets very					
	S	16.0	49.8	24.371	III	rough. Clouds!	17 16.27	+5 24.90	-.155	+.09	41.10
XI	S	16.0	50.2	11.300	II						
	N	47.4	13.8	24.517	III		28 44.01	-6 0.92	-.194	-.10	42.80
XIII	N	51.3	16.2	16.502	III						
	S	16.2	51.3	18.734			21 37.402	+1 1.50	—	+.02	38.92
XIV	S	16.1	51.3	15.314	III						
	N	51.3	16.0	19.079			24 21.19	-1 43.75	-.039	-.03	37.37
VIII	N	48.8	16.7	21.170	III	July 30, 1909					
	S	16.7	48.9	14.505			25 34.06	-3 3.67	-.039	-.05	30.30
IX	N	48.8	16.0	7.171	II						
	S	13.8	46.8	26.568	III		13 39.82	+8 51.22	+1.632	+.15	32.82
	N	49.1	16.0	23.570	III		21 13.22	+1 22.62	+1.748	+.03	37.62
XI	S	18.3	52.0	11.310	II						
	N	50.8	16.8	24.536	III		28 44.19	-6 1.18	-1.049	-.10	41.86
XII	S	16.8	50.5	20.369	III						
	N	51.2	17.1	14.558			19 56.45	+2 40.135	+.428	+.05	37.06
XIII	N	52.4	18.2	16.916	III						
	S	17.6	51.8	19.090			21 37.628	+ 59.91	+.466	+.02	38.02
XIV	S	16.8	51.3	15.523	III						
	N	50.5	16.0	19.235			24 21.41	-1 42.29	-.622	-.03	38.47
XV	S	18.2	53.2	6.320	II	*apparently an error for 29.336					
	N	46.8	12.0	28.336*	IV		33 4.88	-10 24.88	-4.895	-.18	34.92
XVI	N	51.3	16.8	28.601	IV						
	N	50.4	15.8	17.242	III						
	S	16.5	51.3	12.828	II		29 46.936	-7 5.30	+.117	-.12	41.63
							24 39.035	-1 58.33	-.622	-.03	40.05
	S	16.4	51.3	7.830	II		32 4.127	-9 23.035	+.155	-.17	41.08
							26 56.226	-4 16.06	-.583	-.08	39.50
	S	16.3	51.3	22.232	III		25 29.41	-2 49.46	+.194	-.05	40.09
							20 21.509	+2 17.52	-.544	+.04	38.52
XVII	S	16.0	51.0	14.938	III						
	N	51.3	16.3	22.611	IV		26 4.603	-3 25.39	+.233	-.06	39.39
XII	S	18.0	52.4	20.580	III	July 31, 1909					
	N	53.0	18.4	14.848		Brackets rough. Clouds	19 56.65	+2 37.96	+.389	+.05	35.05
V	S	15.2	50.8	26.695	III	August 2, 1909					
	N	51.3	15.4	10.745	II		15 7.306	+7 16.24	+.272	+.13	23.95

Pair.	N.S.	Level. N.	Level. S.	Microm.	Wire.	Date. Remarks.	$\frac{1}{2}(\delta_S+\delta_N)$ ′	″	$\frac{r}{2}(M_S-M_N)$ ′	″	Level ″	Ref. ″	φ ″
VI	S	18.0	54.0	17.253	III								
	N	54.6	18.0	19.824			23	45.558	−1	10.845	+.233	−.02	34.93
VII	S	18.0	54.3	20.111	III								
	N	54.5	18.0	17.394			21	22.475	+1	14.87	+.078	+.02	37.44
VIII	N	54.0	18.0	21.181	III								
	S	18.0	54.4	14.553			25	34.409	−3	2.65	+.039	−.05	31.75
IX	N	52.6	15.9	7.133	II	* apparently an							
	S	17.8	49.5*	26.731	III	error for 54.5	13	40.22	+8	56.76	−1.477	+.15	35.65
	N	52.8	16.0	23.576	III		21	13.63	+1	26.945	−1.360	+.03	39.24
X	N	54.5	17.5	12.717	II								
	S	16.8	53.8	24.340	III		17	16.883	+5	16.99	+.544	+.09	34.51
XI	S	16.7	54.0	11.169	II								
	N	54.2	16.8	24.490	III		28	44.701	−6	3.79	+.117	−.10	40.93
XII	S	16.5	54.4	20.298	III								
	N	54.0	16.0	14.330			19	57.02	+2	44.46	−.35	+.05	41.18
XIII	N	54.2	16.0	16.711	III								
	S	16.0	54.2	18.923			21	38.28	+1	0.95	—	+.02	39.25
XIV	S	16.1	54.3	15.569	III								
	N	54.3	16.0	19.439			24	22.04	−1	46.64	−.039	−.03	35.33
XV	S	16.0	54.3	6.486	II								
	N	54.4	15.7	29.366	IV		33	5.95	−10	21.14	−.078	−.18	44.55
XVI	N	54.5	15.6	28.438	IV								
	N	54.3	15.4	17.125	III								
							29	47.653	−7	4.34	+.194	−.12	43.39
	S	15.2	54.4	12.700	II								
							24	39.76	−1	58.64	+.039	−.03	41.13
							32	4.85	−9	22.16	+.272	−.17	42.79
	S	15.1	54.3	7.699	II								
							26	56.957	−4	16.46	+.117	−.08	40.53
							25	30.135	−2	49.35	+.272	−.05	41.01
	S	15.1	54.3	22.073	III								
							20	22.242	+2	16.36	+.117	+.04	38.76
XVII	S	15.2	54.3	15.126	III								
	N	51.1	11.9	22.622	IV		26	5.373	−3	20.51	−2.525	−.06	42.28
VI	S	13.1	48.9	16.909	III	August 6, 1909							
	N	49.0	13.1	19.439			23	45.93	−1	9.72	+.039	−.02	36.23
VII	S	15.2	51.2	19.820	III								
	N	51.3	15.1	17.064			21	22.895	+1	15.94	—	+.02	38.86
VIII	N	53.0	16.7	21.230	III								
	S	15.4	51.8	14.591			25	34.845	−3	2.955	+.971	−.05	32.81
IX	N	53.3	16.7	7.198	II								
	S	17.8	54.4	26.741	III		13	40.7	+8	55.245	−.855	+.15	35.24
	N	54.4	17.4	23.657	III		21	14.15	+1	24.98	−.155	+.03	39.00

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Pair	N.S.	Level N.	Level S.	Microm.	Wire.	Date. Remarks.	½(δS+δN) ′	½(δS+δN) ″	½(MS−MN) ′	½(MS−MN) ″	Level ″	Ref ″	δ ″
X	N	53.8	16.7	12.673	II								
	S	16.7	54.0	24.323	III		17	17.415	+5	17.74	−.078	+.09	35.17
XI	S	17.1	54.4	10.957	II								
	N	54.3	16.8	24.234	III		28	45.305	−6	2.58	−.155	−.10	42.47
XII	S	16.5	54.4	20.150	III								
	N	54.4	16.5	14.393			19	57.7	+2	38.65	—	+.05	36.40
XIII	N	54.4	16.5	16.700	III								
	S	16.0	53.9	18.805			21	39.08	+0	58.01	+.039	+.02	37.15
XIV	S	16.4	54.4	15.542	III								
	N	54.1	16.0	19.255			24	22.8	−1	42.32	−.272	−.03	40.18
XV	S	18.3	56.8	6.368	II	Definition rough. Clouds!							
	N	56.7	18.1	29.362	IV		33	6.75	−10	24.28	−.117	−.18	42.17
XVI	N	54.4	15.8	28.377	IV								
	N	54.3	15.8	17.084	III								
	S	15.8	54.3	12.583	II		29	48.505	−7	5.88	+.039	−.12	42.54
							24	40.62	−2	0.725	—	−.03	39.86
	S	15.2	54.0	7.554	II		32	5.71	−9	24.465	+.389	−.17	41.46
							26	57.825	−4	19.32	+.350	−.08	38.78
	S	15.2	54.0	21.930	III		25	30.995	−2	51.606	+.389	−.05	39.73
							20	23.11	+2	13.55	+.350	+.04	37.05
XVII	S	16.2	55.0	15.024	III								
	N	46.7	7.7	22.410	IV	Image unsteady	26	6.285	−3	17.49	−6.527	−.06	42.21
VII	S	13.0	46.7	19.920	III	August 7, 1909							
	N	49.6	15.8	17.218			21	23.015	+1	14.595	+2.215	+.02	39.84
VIII	N	*	17.2	20.862	III	* Bubble moved before reading could be completed. Length assumed to be 33.2							
	S	18.0	51.2	14.214			25	34.971	−3	3.20	−.622	−.05	31.10
IX	N	49.3	15.7	7.123	II								
	S	15.8	49.4	26.557	III		13	40.85	+8	52.25	−.078	+.15	33.17
	N	50.7	16.7	23.583	III		21	14.30	+1	21.96	+.855	+.03	37.14
X	N	49.9	15.8	12.493	II								
	S	16.8	51.0	24.216	III		17	17.576	+5	19.745	−.816	+.09	36.60
XI	S	18.0	52.6	10.923	II								
	N	52.9	18.1	24.304	III		28	46.485	−6	5.44	+.155	−.10	40.10
XII	S	16.4	51.3	20.357	III								
	N	51.3	16.1	14.510			19	57.86	+2	41.125	−.117	+.05	38.92
XIII	N	49.2	14.0	16.481	III								
	S	15.9	51.2	18.641			21	39.278	+0	59.52	−1.516	+.02	37.30
XIV	S	16.0	51.2	15.302	III								
	N	52.2	16.9	19.232			24	23.02	−1	48.30	+.739	−.03	35.43
XV	S	16.0	51.3	6.227	II								
	N	51.8	16.3	29.219	IV		33	6.97	−10	24.22	+.311	−.18	42.88

Pair.	N. S.	Level N.	Level S.	Microm.	Wire.	Date. Remarks.	$\frac{1}{2}(\delta_S + \delta_N)$ ′	″	$\frac{n}{2}(M_S - M_N)$ ′	″	Level. ″	Ref. ″	φ. ″
	N	51.3	15.9	28.597	IV								
	N	51.3	15.9	17.264	III								
	S	15.7	51.3	12.800	II		29	48.762	−7	5.96	+.078	−.12	42.76
XVI							24	40.892	−1	59.71	+.078	−.03	41.23
	S	15.7	51.3	9.780	II		32	5.97	−9	24.30	+.078	−.17	41.58
							26	58.100	−4	18.05	+.078	−.08	40.65
	S	15.7	51.3	22.144	III		25	31.256	−2	51.77	+.078	−.05	39.51
							20	23.386	+2	14.48	+.078	+.04	37.98
XVII	S	16.8	52.4	15.148	III								
	N	54.4	18.7	22.962	IV		26	6.562	−3	29.28	+1.516	−.06	38.74
VI	S	15.7	47.5	17.090	III	Aug 9, 1909. Stars very dim. Bisections difficult							
	N	46.0 *	13.7	19.608		*Moving when read.	23	46.242	−1	9.39	−1.36	−.02	35.47
VII	S	50.6	18.1	20.240	III								
	N	18.2	51.0	17.554			21	23.255	+1	14.01	+.194	+.02	37.50
VIII	N	16.7	49.3	21.132	III								
	S	51.2	18.6	14.538			25	35.223	−3	1.72	−1.477	−.05	31.98
	N	48.8	15.8	7.162	II								
IX	S	14.3	47.4	26.609	III		13	41.15	+8	52.665	+1.127	+.15	35.03
	N	49.3	16.0	23.615	III	Image unsteady	21	14.60	+1	22.51	+1.399	+.03	38.54
X	N	46.5	13.0	12.597	II								
	S	17.8	51.3	24.368	III		17	17.898	+5	21.065	−3.73	+.09	35.32
XI	S	16.7	50.4	11.002	II								
	N	50.1	16.3	24.374	III		28	45.845	−6	5.19	−.272	−.10	40.28
XII	S	16.0	50.1	20.164	III	Bisection rough. Image unsteady, Clouds!							
	N	50.0	15.8	14.346			19	58.18	+2	40.33	−.117	+.05	38.44
XIII	N	54.0 *	18.8	16.830	III	*Bubble moving when read.							
	S	16.9	51.2	18.875			21	39.674	+0	56.35	+1.826	+.02	37.87
XIV	S	16.9	51.3	15.503	III								
	N	50.3	16.0	19.324			24	23.46	−1	45.29	−.739	−.03	37.40
XV	S	16.0	50.4	6.372	II								
	N	52.8	18.0	29.453	IV		33.	7.41	−10	26.675	+1.709	−.18	42.26
	N	51.3	16.5	28.408	IV								
XVI	N	51.0	16.0	17.092	III								
	S (832)	16.3	51.2	12.590	II	*832 Safford.	29	49.276	−7	6.54	+.117	−.12	42.73
							24	41.436	−2	0.75	−.194	−.03	40.46
VII	S	16.5	51.3	20.150	III	August 10, 1909							
	N	53.4	18.0	17.488			21	23.375	+1	13.35	+1.399	+.02	38.14
VIII	N	53.6	18.0	20.995	III								
	S	18.0	53.9	14.240			25	35.349	−3	6.155	−.117	−.05	29.03
X	N	53.9	16.8	12.816	II	Rough bisection. Clouds							
	S	18.6	55.7	24.447	III		17	18.059	+5	17.215	−1.399	+.09	33.96

Pair.	N.S.	Level. N.	Level. S.	Microm.	Wire.	Date. Remarks.	$\frac{1}{2}(\delta_S+\delta_N)$ ′	″	$\frac{\kappa}{2}(M_S-M_N)$ ′	″	Level ″	Ref ″	ϕ ″
XI	S	13.0	50.7	10.876	II								
	N	49.2	11.4	24.161	III		28	46.025	−6	2.80	−1.205	−.10	41.92
XII	S	16.2	54.3	20.232	III								
	N	54.3	16.0	14.514			19	58.34	+2	37.58	−.078	+.05	35.89
XIII	N	56.6	18.0	16.679	III								
	S	16.0	54.4	18.797			21	39.872	+0	58.37	+1.632	+.02	39.89
XIV	S	15.7	54.3	15.401	III								
	N	55.3	16.7	19.303			24	23.68	−1	47.52	+.777	−.03	36.91
XV	S	15.8	54.4	6.215	II								
	N	54.4	15.8	29.288	IV		33	7.63	−10	26.46	—	−.18	40.99
XVI	N	53.0	14.0	28.532	IV								
	N	53.0	14.0	17.213	III								
	S	13.0	52.0	12.662	II		29	49.533	−7	7.98	+.777	−.12	42.21
							24	41.708	−2	2.105	+.777	−.03	40.35
	S	11.4	50.7	7.633	II		32	6.75	−9	26.565	+1.904	−.17	41.92
							26	58.925	−4	20.69	+1.904	−.08	40.06
	S	11.4	50.7	22.028	III		25	32.039	−2	52.99	+1.904	−.05	40.90
							20	24.214	+2	12.695	+1.904	+.04	38.85
XVII	S	12.0	51.3	15.015	III								
	N	53.2	14.0	22.708	IV		26	7.393	−3	25.94	+1.554	−.06	42.95
VIII	N	49.0	13.0	20.809	III	August 11, 1909							
	S	15.1	51.3	14.176			25	35.475	−3	2.79	−1.709	−.05	30.93
IX	N	50.1	14.0	6.995	II								
	S	13.0	49.3	26.428	III		13	41.45	+8	52.22	+.700	+.15	34.52
	N	50.4	14.0	23.440	III		21	14.9	+1	22.34	+.816	+.03	38.09
X	N	54.3	17.8	12.760	II								
	S	17.8	54.4	24.400	III		17	18.22	+5	17.46	−.039	+.09	35.73
XII	S	16.7	54.0	20.394	III								
	N	54.4	16.8	14.722			19	58.5	+2	36.30	+.194	+.05	35.04
XIII	N	51.8	14.0	16.670	III								
	S	13.5	51.3	18.818			21	40.07	+0	59.19	+.389	+.02	39.67
XIV	S	16.2	54.0	15.495	III								
	N	54.4	16.5	19.400			24	23.9	−1	47.61	+.272	−.03	36.53
XV	S	14.5	52.7	6.374	II								
	N	47.6	9.5	29.269	III	Rough. Image unsteady	33	7.85	−10	27.615	−3.924	−.18	36.13
XVI	N	51.1	13.0	28.504	IV								
	N	51.2	13.0	17.205	III								
	S	12.0	50.7	12.631	II		29	49.79	−7	8.06	+.544	−.12	42.15
							24	41.98	−2	2.74	+.583	−.03	39.79
	S	12.0	51.0	7.635	II	Image unsteady	32	7.01	−9	25.74	+.428	−.17	41.63
							26	59.20	−4	20.42	+.466	−.08	39.17

Pair.	N.S.	Level. N	Level. S	Microm.	Wire.	Date. Remarks.	$\frac{1}{2}(\delta_S+\delta_N)$ ′	″	$\frac{r}{2}(M_S-M_N)$ ′	″	Level. ″	Ref. ″	φ. ″
XVI (Cont)	S	12.0	51.0	22.025	III		25	32.3	−2	52.485	+.428	−.05	40.19
							20	24.49	+2	12.83	+.466	+.04	37.83
XVII	S	11.4	50.3	14.760	III								
	N	53.2	14.0	22.546	IV		26	7.67	−3	28.51	+2.137	−.06	41.24
VII	S	16.3	50.3	20.196	III	August 12, 1909							
	N	48.3	14.0	17.419			21	23.615	+1	16.52	−1.671	+.02	38.48
VIII	N	51.2	16.7	21.186	III								
	S	16.3	51.1	14.478			25	35.601	−3	4.86	+.194	−.05	30.88
XI	S	16.7	53.0	11.090	II								
	N	54.4	18.0	24.547	III		28	46.303	−6	7.54	+1.049	−.10	39.71
XII	S	17.5	54.4	20.430	III								
	N	53.9	16.7	14.591	III	Rough. Heavy haze	19	58.67	+2	40.905	−.505	+.05	39.12
X	N	51.0	14.0	12.728	II	August 13, 1909							
	S	14.3	51.2	24.346	III		17	18.38	+5	16.85	−.194	+.09	35.13
XI	S	14.0	51.3	10.988	II								
	N	51.2	13.6	24.359	III		28	46.401	−6	5.165	−.194	−.10	40.94
XII	S	11.5	49.5	20.085	III								
	N	49.6	11.3	14.307			19	58.84	+2	39.23	−.039	+.05	38.08
XIII	N	53.3	15.1	16.820	III								
	S	15.8	54.0	18.927			21	40.37	+0	58.065	−.544	+.02	37.91
XIV	S	16.0	54.4	15.559	III								
	N	54.4	16.0	19.475			24	24.18	−1	47.91	—	−.03	36.25
XV	S	13.0	51.8	6.587	II								
	N	54.4	15.8	29.690	IV		33	8.21	−10	27.28	+2.098	−.18	42.85
XVI	N	54.0	15.0	28.434	IV								
	N	54.0	15.0	17.167	III								
	S	15.2	54.3	12.657	II		29	50.148	−7	5.41	−.194	−.12	44.43
							24	42.32	−1	59.33	−.194	−.03	42.77
	S	15.1	54.3	7.672	II		32	7.374	−9	22.79	−.155	−.17	44.26
							26	59.546	−4	16.705	−.155	−.08	42.61
	S	15.1	54.3	22.056	III		25	32.642	−2	49.71	−.155	−.05	42.73
							20	24.814	+2	16.39	−.155	+.04	41.09
XVII	S	15.9	55.1	15.020	III								
	N	54.4	15.0	22.759	IV		26	8.07	−3	27.215	−.622	−.06	40.17
VIII	N	51.8	16.0	21.010	III	August 14, 1909							
	S	15.5	51.3	14.291			25	35.853	−3	5.165	+.389	−.05	31.03
IX	N	51.2	15.1	7.055	II								
	S	15.0	51.2	26.471	III		13	41.63	+8	51.74	+.039	+.15	33.56
	N	51.2	14.6	23.484	III	Image unsteady	21	15.11	+1	22.315	−.155	+.03	37.30
X	N	51.0	14.0	12.677	II								
	S	14.1	51.2	24.297	III		17	18.46	+5	16.91	−.117	+.09	35.34

Pair	N.S.	Level N	Level S	Microm.	Wire	Date Remarks	$\frac{1}{2}(\delta_S+\delta_N)$	$\frac{r}{2}(M_S-M_N)$	Level	Ref.	ϕ
							′ ″	′ ″	″	″	″
XI	S	14.1	51.8	10.914	II						
	N	54.0	16.3	24.350	III		28 46.499	−6 6.96	+1.671	−.10	41.11
XII	S	16.0	54.0	20.373							
	N	54.4	16.0	14.692	III		19 59.01	+2 36.55	+.155	+.05	35.76
XIII	N	54.4	16.0	16.822							
	S	16.0	54.4	18.891	III		21 40.52	+0 57.01	—	+.02	37.55
XIV	S	15.8	54.4	15.671							
	N	57.0	18.0	19.551	III		24 24.32	−1 46.91	+1.865	−.03	39.28
XV	S	11.7	50.8	6.272	II	Image unsteady					
	N	54.5	15.5	29.513	IV		33 8.39	−10 31.095	+2.914	−.18	40.03
XVI	N	54.0	15.0	28.559	IV						
	N	54.3	15.0	17.242	III						
	S	14.8	54.3	12.634	III		29 50.327	−7 12.80	−.039	−.12	37.37
							24 42.49	−2 6.98	+.078	−.03	35.56
	S	14.7	54.3	7.629	II		32 7.556	−9 27.42	—	−.17	39.97
							26 59.719	−4 21.60	+.117	−.08	38.16
	S	14.4	54.0	22.000	III		25 32.813	−2 54.695	+.233	−.05	38.30
							20 24.976	+2 11.12	+.350	+.04	36.49
XVII	S	14.5	54.4	15.100	III						
	N	55.0	15.1	22.834	IV		26 8.27	−3 27.08	+.466	−.06	41.60

SECTION IV.

Reduction of Observations.

In so far as time permitted the observations were reduced during the period of the Observatory work, so that it was possible to test the results to some extent from day to day. The reductions, with the results, are given in the final columns of Table IV.

Early in the work it was noticed that there were variations of considerable magnitude in the results obtained. For instance, on July 17th the results ranged from 31.98 for pair VIII to 39.35 for pair XV. These discrepancies did not tend to become less marked as the Observer grew more familiar with the Instrument and with the method of observation. On July 27th pair VIII gave 31.68 and pair XV gave 41.66. It was noticed, however, that the results are reasonably consistent when those for a single pair are grouped together, as in Table V. This fact led to a suspicion of errors in the declinations used. A brief search served to disclose an error in the declination of one of the stars of pair VIII as given by Safford of sufficient size to account for the low values given by that pair. But in the case of a number of other pairs which constantly gave values at some distance from the mean, no such error in declination was discovered during the brief search made at the time.

It was thought best to leave for a later period a complete discussion of the question of the declinations, (See

TABLE V.

Results by Pairs.

Wires used.

Date. 1909.	Pair II " of ϕ	Pair II Wire S N	Pair III " of ϕ	Pair III Wire S N	Pair IV " of ϕ	Pair IV Wire S N	Pair V " of ϕ	Pair V Wire S N	Pair VI " of ϕ	Pair VI Wire S N	Pair VII " of ϕ	Pair VII Wire S N
July 8			40.22	III	35.40	IV III	32.65	IV II				
12	34.25	IV II	38.38	III			37.83	III			39.61	III
14			35.72	III	31.88	IV II	36.65	III			38.01	III
17							34.67	III	37.09	III	38.52	III
19					32.25	IV II	36.11	III	38.04	III	38.19	III
21					32.76	IV II	38.01	III	33.97	III	40.25	III
22							38.02	III	35.70	III	38.94	III
24							30.91	III II	31.63	III	37.00	III
26							31.10	III II	38.04	III	39.36	III
27									36.47	III	37.98	III
28									38.27	III	38.48	III
29												
30												
31												
August 2							23.95	III II	34.93	III	37.44	III
6									36.23	III	38.86	III
7											39.84	III
9									35.47	III	37.50	III
10											38.14	III
11												
12											38.48	III
13												
14												
Number		1		3		4		10		11		16
Average	[34.25]		38.107		33.072		33.990		35.985		38.538	
δ Correction	-.33		-.61		-.7		+.65		+.72		-1.13	
Corr. Aver.	[33.92]		37.50		32.37		34.64		36.70		37.41	

Date 1909	Pair VIII "of φ	Wire S N	Pair IX_1 "of φ	Wire S N	Pair IX_2 "of φ	Wire S N	Pair X "of φ	Wire S N	Pair XI "of φ	Wire S N	Pair XII "of φ	Wire S N	Pair XIII "of φ	Wire S N	Pair XIV "of φ	Wire S N
July 8																
12	34.86	III														
14																
17	31.98	III	35.29	III II	34.06	III			38.46	III	37.61	III	38.60	III	37.72	III
19	31.26	III	33.75	III II												
21	32.36	III	35.35	III II	40.08	III	43.26	IV III	37.86	III	38.05	III	35.12	III	37.84	III
22	32.07	III	36.94	III II	37.46	III	37.85	III	37.83	III	39.40	III	37.86	III	37.02	III
24	32.00	III	34.18	III II	37.26	III	36.26	IV III	41.48	II III	37.74	III	36.70	III	36.70	III
26	32.07	III	34.86	III II	38.69	III	35.64	III II	39.98	II III	39.26	III	38.35	III	37.41	III
27	31.68	III	32.62	III II	39.12	III	34.10	III II	40.79	II III	36.76	III	40.06	III	34.21	III
28	31.77	III	35.21	III II	39.45	III	36.90	IV III	41.65	II III	36.04	III	37.11	III	36.95	III
29	31.46	III					41.10	III II	42.80	II III			38.92	III	37.37	III
30	30.30	III	32.82	III II	37.62	III			41.86	II III	37.06	III	38.02	III	38.47	III
31											35.05	III		″		
August 2	31.75	III	35.65	III II	39.24	III	34.51	III II	40.93	II III	41.18	III	39.25	III	35.33	III
6	32.81	III	35.24	III II	39.00	III	35.17	III II	42.47	II III	36.40	III	37.15	III	40.18	III
7	31.10	III	33.17	III II	37.14	III	36.60	III II	40.10	II III	38.92	III	37.30	III	35.43	III
9	31.98	III	35.03	III II	38.54	III	35.32	III II	40.28	II III	38.44	III	37.87	III	37.40	III
10	29.03	III					33.96	III II	41.92	II III	35.89	III	39.89	III	36.91	III
11	30.93	III	34.52	III II	38.09	III	35.73	III II			35.04	III	39.67	III	36.53	III
12	30.88	III							39.71	II III	39.12	III				
13							35.13	III II	40.94	II III	38.08	III	37.91	III	36.25	III
14	31.03	III	33.56	III II	37.30	III	35.34	III II	41.11	II III	35.76	III	37.55	III	39.28	III
Number.		19		15		14		15	-	17		18		17		17
Average.	31.648		34.546		38.075		36.458		40.598		37.544		38.078		37.118	
δ Correction	+4.72		-.44		-.46		-.28		-.04		-.01		+.2		-1.55	
Corr. Aver.	36.37		34.11		37.62		36.18		40.56		37.53		38.28		35.57	38

Date	Pair XV		Pair XVI₁		Pair XVI₂		Pair XVI₃		Pair XVI₄		Pair XVI₅		Pair XVI₆		Pair XVII	
1909	" of φ	Wire S N	" of φ	Wire S N	" of φ	Wire S N	" of φ	Wire S N	" of φ	Wire S N	" of φ	Wire S N	" of φ	Wire S N	" of φ	Wire S N
July 8																
12																
14																
17	40.35	II IV														
19																
21	42.19	II IV	37.91	III IV	35.69	III	37.79	III IV	35.55	III	38.20	IV	35.96	IV III		
22	42.65	II IV	37.98	III IV	36.34	III	36.68	III IV	35.05	III	35.91	IV	34.27	IV III		
24	41.59	II IV	42.87	II IV	39.59	II III	41.45	II IV	38.16	II III	39.97	III IV	36.68	III		
26	42.91	II IV	41.58	II IV	38.51	II III	40.23	II IV	37.17	II III	40.35	III IV	37.29	III	39.60	III IV
27	41.66	II IV	41.04	III IV	37.60	III	43.55	II IV	40.11	II III	42.36	III IV	38.93	III	43.06	III IV
28	41.05	II IV	42.20	II IV	40.30	II III	40.89	II IV	39.00	II III	39.65	III III	37.81	III	39.84	III
29																
30	34.92	II IV	41.63	II IV	40.05	II III	41.08	II IV	39.50	II III	40.09	III IV	38.52	III	39.39	III IV
31																
August 2	44.55	II IV	43.39	II IV	41.13	II III	42.79	II IV	40.53	II III	41.01	III IV	38.76	III	42.28	III IV
6	42.17	II IV	42.54	II IV	39.86	II III	41.46	II IV	38.78	II III	39.73	III IV	37.05	III	42.21	III IV
7	42.88	II IV	42.76	II IV	41.23	II III	41.58	II IV	40.05	II III	39.51	III IV	37.98	III	38.74	III IV
9	42.26	II IV	42.73	II IV	40.46	II III										
10	40.99	II IV	42.21	II IV	40.35	II III	41.92	II IV	40.06	II III	40.90	III IV	38.85	III	42.95	III IV
11	36.13	II III	42.15	II IV	39.79	II III	41.53	II IV	39.17	II III	40.19	III IV	37.83	III	41.24	III IV
12																
13	42.85	II IV	44.43	II IV	42.77	II III	44.26	II IV	42.61	II III	42.73	III IV	41.09	III	40.17	III IV
14	40.03	II IV	37.37	III IV	35.56	III	39.97	II III	38.16	II III	38.30	III IV	36.49	III	41.60	III IV
Number		16		15		15		14		14		14		14		11
Average	41.198		41.520		39.282		41.084		38.850		39.921		37.680		41.007	
δ Correction	-.5		-.31		-.33		+1.69		+1.68		-37		-.38		-.41	
Corr. Aver.	40.70		41.21		38.95		42.77		40.53		39.55		37.30		40.60	

section V), and, in so far as it was possible, to test the instrumental values for constant errors. In passing it may be noted that the differential refraction corrections, though constant for any pair throughout the period of observations, were nevertheless too small to cause such variation, the maximum value used in any case being only 0.23".

An examination of the level corrections as given in Table IV will show that during the first part of the period these are large enough to cause the variations under discussion. Later on the attempt was made, with some degree of success, to reduce the level corrections to smaller amounts by "checking up" the level reading with the proper slow motion screw after the telescope had been reversed between the transits. In cases of pairs where the right ascensions of the two stars differed by less than three minutes of time it was difficult to do this level checking with any degree of accuracy. Pairs X, XIII, XV, and XVII, which were the only ones with time intervals of less than three minutes, still show relatively large corrections. Excepting these pairs there was but a single level correction after July 24th that exceeded 2", the correction for pair VII on August 7th which was 2.215". For the rest of the observations less than one correction in five exceeded 1". Since the level correction is not constant but compensating in the case of any particular pair, it was not of course to be expected that

the regular variation of a pair from the mean could be explained by assuming an error in the level constant. Moreover, a comparison of the earlier results in any pair with the later, and of the results for pairs X, XIII, XV, and XVII with the results for the other pairs does not reveal irregularities that appear to be traceable to such an error.

The micrometer constants remain to be considered. As a beginning, an attempt was made to test the screw for irregularities by taking transits of slow moving stars. The micrometer box was rotated through ninety degrees thus placing the movable wires parallel to the meridian. A suitable star of known declination having been selected, a record of its transits was made with the chronograph, the wire used being advanced beyond the star one or more revolutions of the micrometer head after each transit. As the value of this work depended almost entirely on the possibility of getting the transits accurately the tremor due to city traffic, (see Section III), became a matter of great importance. It was very soon apparent that the results of this method of testing could hardly be trusted in work of this character. The length of time devoted to observations made it impossible to carry out any extended test by other methods and no final conclusion was reached as to the regularity of the screw.

A test of the wire intervals attempted at the same time and by similar ~~intervals~~ methods was of course open to the same difficulties. These intervals were, however, tested indirectly

as follows;

In Table V with each result is placed the wire or wires used in the observation. Of the 290 results there given 146 were determined from observations in which a single wire was used. In the case of the remaining 144 results different wires were used in observing the north and south stars of the pair. In a large majority of the cases where the north star was observed on the wire of lower number the result is lower than 38". Where the north star was observed on the wire of higher number the result is usually more than 38". The arithmetical average for all such observations on a single pair is invariably lower in the former case and higher in the latter with the exception of the following cases; The single observation of pair XV made on August 11 under adverse conditions with the south star on wire II and the north star on wire III gives 36".08 as a result. The mean of three observations of pair X with the north star on wire III and the south star on wire IV gives 38".81, the high average in this case being due to the observation of July 21 which gave 43".26, one of the largest results obtained during the work. There was probably an error in the level reading. (See Table IV.)

Table VI gives the material from which the statements above are gleaned, the three columns under "Average Results" giving respectively, the averages for observations with the south star on the wire of higher number, for observations on a single wire, and for observations with the north star on the wire of higher number. Before this Table was constructed the

final corrections of the declinations were made. It seems to be pretty conclusively shown by the Table that the values used for the wire intervals were not accurate, and that in all probability a more satisfactory value of the latitude could be obtained by rejecting the values in which two wires were used unless it were possible to correct the wire intervals.

The last two columns of the Table give the corrections in the cases of pairs where some of the observations were on one wire and others on more than one. Unfortunately the data is insufficient to permit of the determination of a correction. It is possible that there may be in the discussion above the suggestion of a satisfactory way of determining wire intervals. It has the advantage of giving an interval determined under working conditions.

TABLE VI.

Average results for Pairs grouped by wires used.

The columns give; the pair, the number of observations on two wires and on one wire, the wire used, the average results with the south star on the wire of higher number, with both stars on the same wire, with the north star on the wire of higher number, the correction with the wire interval.

A parenthesis in the column of average results indicates that the value is from a single observation.

Pair	Number of Observations: On two wires	On one wire	Wires: II	III	IV	Average results: S on higher number	On one wire	N on higher number	Correction	Wire Entered
II	1		N		S	(33.92)				
III		3		NS			37.50			
IV	1			N	S	(34.70)				
IV	3		N		S	31.60				
V	1		N		S	(33.30)			(4.23)	II-IV
V	2*		N	S		31.65			5.88	II-III
V		6		NS			37.53			
VI		11		NS			36.70			
VII		16		NS			37.41			
VIII		19		NS			36.37			
IX_1	15		N	S		34.11				
IX_2		14		NS			37.62			
X	3			N	S	38.81			(1.24)	III-IV
X	11		N	S		35.41			(2.16)	II-III
X		1		NS			(37.57)			
XI		3		NS			38.01		3.09	II-III
XI	14		S	N				41.10		
XII		18		NS			37.53			
XIII		17		NS			38.28			
XIV		17		NS			35.57			
XV	15		S		N			41.04		
XV	1		S	N				(36.08)		
XVI_1	4			S	N			38.27		
XVI_1	11		S		N			42.28		
XVI_2		4		NS			35.97		4.07	II-III
XVI_2	11		S	N				40.04		
XVI_3	2			S	N			38.93		
XVI_3	12		S		N			43.42		
XVI_4		2		NS			36.98		4.14	II-III
XVI_4	12		S	N				41.12		
XVI_5		2			NS		36.68		3.35	III-IV
XVI_5	12			S	N			40.03		
XVI_6	2			N	S	34.74			2.99	III-IV
XVI_6		12		NS			37.73			
XVII		1		NS			(39.43)		(1.28)	III-IV
XVII	10			S	N			40.71		
	143*	146								

*Disregarding a very erratic result, 23.95, probably due to an error in the star observed.

SECTION V.

Final determination of the declination.

As indicated in section IV, it was assumed that the single determination of the declination from the Safford and Ambronn catalogues was sufficiently accurate for use in the reductions, and that a correction could be added to the results when the final determination of the declination had been made. It was assumed that a correction of the declination for 1909.0 would be sufficiently accurate without determining specifically the corrections for the apparent declinations as given in Table III.

Table VII gives a list of the catalogues used in determining the final values of the declination for 1909.0. The epoch of the catalogue and the method of reduction were the main factors in deciding the weight of the declinations taken from it. Table VIII gives the final correction for each pair for $\frac{1}{2}(\delta_S+\delta_N)$. These corrections were added to the results which were used in the final determination of the most probable value of the latitude.

TABLE VII.

Star Catalogues used for the final Determination of δ.

The columns from the left are as follows; 1) name of catalogue, and abbreviation used in Table X, 2) epoch, 3) method used in reducing the declination to 1909.0, 4) weight used in getting the final value of the declination.

Catalogue. Name-Abbreviation#		Epoch.	Method of Reduction.	Weight.
Safford	S	1875	(See Sect. II, p 14.)	1.
Paris	P	1875	Secular variation used.	1.
Greenwich	G_{90}	1890	Secular variation used.	2.
Greenwich	G_{00}	1900	Secular variation used.	3.
Ambronn	A	1900	Yearly variation used.	2.
Newcomb	N	1900	Centenial variation used.	2.
Boss	B	1900	Secular variation used.	3.
Amer.Naut.Alm.	AN	1909	Direct reading	5.
Brit. Naut.Alm.	BN	1909	Direct reading.	5.

#See Bibliography for full titles.

TABLE VIII.

Declination Corrections.

The columns from the left are as follows; 1) the pair, 2) star number or constellation, 3) catalogue, (For abbreviations see Table IX.), 4) catalogue star number, 5) magnitude, 6) δ for 1909.0, 7) " of corrected δ , 8) value of $\frac{1}{2}(\delta_S+\delta_N)$ used in the reductions, 9) corrected value of $\frac{1}{2}(\delta_S+\delta_N)$, 10) the correction to be added to the results of the reductions.

Pair	Name or Constellation	Catalogue	Number	Magnitude	δ 1909.0	" of Corrected δ	" of $\frac{1}{2}(\delta_s+\delta_n)$ as used	As corrected	Correction to be added to results.
	Draco	S	362	5	54° 54′ 22.3″		"	"	"
		A	4785	5.5	22.3				
		P	18727	5.6	22.3				
		B	3856	5.5	22.38				
						22.33			
	48 χ Bootis	S	372	5	29 30 6.0				
		A	4820	5.5	4.2				
		P	18905	6.	6.0				
		B	3883	5.4	5.62				
						5.32			
II							14.15	13.82	−0.33
	Bootis	S	382	6	25 17 11.2				
		A	4852	6.5	10.9				
		G_{90}	3868	6.4	8.2				
		P	19036	6.7	9.8				
						9.87			
	12 i Draco	S	400	3	59 17 4.3				
		A	4880	3.5	4.9				
		G_{90}	3907	3.4	4.40				
		G_{00}	3110	3.4	4.07				
		B.N.		3.4	4.37				
		N.	979	3.4	4.30				
		P	19195	3	5.4				
		B	3936	3.4	4.34				
						4.42			
III							7.75	7.14	−0.61
	4 θ Cor. Bor.	S	415	4.	31 39 58.3				
		A	4908	4.5	(45*) 56.3				
		G_{90}	3925	4.3	56.88				
		N	985	4.2	56.89				
		P	19339	4.5	57.9				
		B	3953	4.3	56.63				
						56.93			
	Draco	S	444	6.5	52 38 51.3				
		A	4972	5.8	50.6				
		P	19598	6.	51.5				
		B	4004	5.6	51.62				
						51.26			
IV							54.8	54.10	−0.7

* This has been carefully reread from the catalogue and checked. It appears to be a typographical error and is changed to 39′ in use. The identity of the star is unquestioned.

Pair	Name or Constellation	Catalogue	Number	Mag.	δ 1909.0	" of corrected δ	" of ½($\delta_S+\delta_N$) as used	" of ½($\delta_S+\delta_N$) as corrected	correction to be added to results
	12 λ Cor. Bor.	S	470	6	38° 12′ 33.4″				″
		A	5048	5.7	32.4				
		P	19891	5	32.4				
		B	4057	5.7	33.56				
						33.04			
	6 υ Herc.	S	484	5.4	46 17 19.1				
		A	5090	4.9	21.6				
		P	20089	4.5	23.0				
		B	4089	4.8	20.03				
						20.77			
V							26.25	26.90	+0.65
	18 ν Cor. Bor.	S	509	6.5	29 22 29.3				
		A	5168	6.0	30.6				
		G_{90}	4099	5.8	29.26				
		G_{00}	3237	5.8	29.44				
		P	20388	6.	30.47				
		B	4146	5.9	29.28				
						29.63			
	Draco	S	529	6.5	55 24 40.8				
		A	5215	6.0	41.2				
		N	1048	5.7	42.3				
		B	4187	5.8	42.21				
						41.80			
VI							35.0	35.72	+0.72
	30 g Herc.	S	537	var	42 4 55.9				
		A	5236	var	53.6				
		G_{90}	4156	var	53.74				
		N	1054	5.0	54.10				
		B	4201	var	52.70				
						53.69			
	35 σ Herc.	S	552	4.5	42 37 27.2				
		A	5258	4.5	26.8				
		G_{90}	4180	4.2	27.49				
		N	1062	4.3	27.02				
		P	20836	4	27.0				
		B	4220	4.2	27.28				
						27.15			
VII							41.55	40.42	−1.13

Pair	Name or Constellation	Catalogue	Number	Mag.	δ 1909.0	" of corrected δ	" of $\frac{1}{2}(\delta_S + \delta_N)$ As used	As corrected	Correction to be added to results. "
	16 Draco.	S	558	5.3	53 4 57.3				
		A	5272	5.6	55.8				
		B	4229	5.8	56.96				
						56.63			
	40 ζ Herc.	S	567	3.2	31 45 50.3				
		A	5298	3.2	46 2.2				
		G_{90}	4195	3.1	1.21				
		G_{00}	3286	3.1	1.42				
		B.N		3.0	1.92				
		N	1067	3.0	1.80				
		P	21018	3.	45 49.2				
		B	4246	2.8	46 1.29				
						(46′) 0.40			
VIII							53.8	58.52	+4.72
	Herc.	A	5328	6.1	42 24 4.3				
		G_{90}	4216	6.4	2.76				
						3.03			
	Herc.	A	5345	6.5	42 2 54.8				
		G_{90}	4226	6.6	55.38				
		P	21289	6.7	55.6				
						55.19			
IX_1							29.55	29.11	−0.44
	Herc	A	5385	6.5	42 39 11.2				
		G_{90}	4249	6.9	8.61				
						9.90			
IX_2							33.0	32.54	−0.46
	——	S	619	6	43 56 7.7				
		P	21652	7	8.6				
		B	4349	6.7	7.02				
						7.47			
	Herc.	S	626	6	40 38 5.1				
		A	5437	6.5	4.6				
		G_{90}	4289	6.3	4.63				
		N	1091	6.3	4.75				
		P	21716	7	6.2				
		B	4359	6.4	4.37				
						4.76			
X							6.4	6.12	−0.28

Pair	Name or Constellation	Catalogue	Number	Mag.	δ 1900.0	" of corrected δ	" of $\frac{1}{2}(\delta_S+\delta_N)$ As used	As corrected	Correction to be added to results.
	72 w. Herc.	S	652	5.6	32° 35′ 4.0″				″
		A	5505	5.7	5.1				
		G_{90}	4339	5.4	3.33				
		N	1106	5.4	3.16				
		B	4403	5.5	2.95				
						3.60			
	23 β Draco	S	673	3.2	52 22 6.1				
		A	5567	3.0	6.1				
		A.N.		3.	6.38				
		G_{90}	4366	3.0	6.34				
		B.N.		3.	6.39				
		N	1119	3.0	6.30				
		P	22344	2.3	6.7				
		B	4443	2.8	6.18				
						6.32			
XI							5.0	4.96	−0.04
	86 μ Herc.	S	701	3.4	27 46 24.2				
		A	5645	3.6	23.6				
		A.N.		3.5	24.26				
		G_{90}	4410	3.5	24.42				
		G_{00}	3473	3.5	24.42				
		B.N.		3.5	24.26				
		N.	1137	3.5	24.13				
		B	4497	3.4	24.03				
						24.19			
	32 ξ Draco	S	719	3.4	56 53 11.7				
		A	5700	4.0	12.2				
		G_{90}	4446	3.9	11.95				
		G_{00}	3497	3.9	11.62				
		N	1146	3.9	12.14				
		P	23070	5	8.5				
		B	4531	3.8	11.98				
						11.68			
XII							17.95	17.94	−0.01
	33 γ Draco	S	722	2.3	51 29 56.9				
		A	5714	2.5	57.2				
		A.N.		2.5	57.34				
		G_{90}	4454	2.4	57.25				
		G_{00}	3505	2.4	56.72				
		B.N		2.4	57.34				

Pair	Name or Constellation	Catalogue	Number	Mag.	δ 1909.0	" of corrected δ	" of ½(δ$_S$+δ$_N$) As used	As corrected	Correction to be added to results
					° ′ ″				″
		N	1151	2.4	51 29 57.25				
		P	23140	2.	57.8				
		B	4541	2.2	57.10				
						57.21			
	Herc	S	727	6.5	33 13 0.5				
		A	5733	6.2	0.6				
		P	23226	6.	0.6				
						0.58			
XIII							28.7	28.9	+ 0.2
	99b Herc	S	737	5.	30 32 54.2				
		A	5769	5.3	52.5				
		B	4582	5.2	53.90				
						53.48			
	Draco	S	750	6.	54 15 31.5				
		A	5804	6.2	22.7				
		B	4609	6.2	32.62				
						29.13			
XIV							42.85	41.30	− 1.55
	1 K Lyrae	S	764	5.4	36 1 21.8				
		A	5855	4.5	22.9				
		G_{90}	4552	4.4	22.9				
		B	4639	4.5	22.61				
						22.65			
	Draco.	S	774	5	49 4 32.0				
		A	5873	5.2	27.9				
		B	4653	5.3	31.01				
						30.14			
XV							26.9	26.4	− 0.5
	Draco	S	796	5.6	52 16 51.5				
		A	5945	5.4	51.8				
		G_{90}	4640	5.4	51.18				
		P	24376	6.7	51.9				
		B	4711	5.5	51.33				
						51.48			
	Draco	S	811	6.	52 6 35.9				
		A	5979	6.2	35.4				
		P	24536	6.7	35.7				
		B	4733	6.0	36.18				
						35.85			

Pair	Name or Constellation	Catalogue	Number	Mag	δ 1909.0	" of corrected δ	" of ½($\delta_S+\delta_N$) As used	As corrected	Correction to be added to results "
	8 Lyrae	S	832	6.3	32° 42′ 26.8				
		A	6039	6.1	26.0				
		B	4772	6.0	26.11				
						26.19			
$\underline{XVI}_1$							39.15	38.84	−0.31
$\underline{XVI}_2$							31.35	31.02	−0.33
	Lyra	S	852	6	32 47 1.4				
		A	6099	5.5	7.6				
		P	25075	6.	8.2				
		B	4815	5.5	2.95				
						4.81			
$\underline{XVI}_3$							26.45	28.14	+1.69
$\underline{XVI}_4$							18.65	20.33	+1.68
	14 γ Lyrae	S	856	3.4	32 33 51.9				
		A	6112	3.6	51.1				
		AN		3.3	51.20				
		G_{90}	4788	3.2	51.11				
		G_{00}	3696	3.2	51.08				
		BN		3.3	51.20				
		N	1220	3.3	51.07				
		P	25148	3.	51.8				
		B	4824	3.2	50.90				
						51.18			
$\underline{XVI}_5$							51.7	51.33	−0.37
$\underline{XVI}_6$							43.9	43.52	−0.38
	Lyra	S	873	6.	31 36 32.0				
		A	6159	5.9	32.6				
		B	4860	6.0	28.84				
						30.62			
	51 Draco	S	879	6.	53 15 23.1				
		A	6171	5.6	23.8				
		B	4869	5.5	23.75				
						23.66			
$\underline{XVII}$							27.55	27.14	−0.41

SECTION VI.

Determination of the most probable value of the Latitude and of the probable error.

Hayford's description* of the application of Least Squares to this problem has been followed in the final determination.

If p is the total number of pairs observed, n the total number of observations, and $[\Delta\Delta]$ the sum of the squares of the residuals of all observations, obtained in each instance by subtracting the mean result for a pair from the various particular results for that pair, — then the probable error, e , of a single observation is given by the formula;

$$e = \sqrt{\frac{(0.455)\cdot[\Delta\Delta]}{n-p}} \qquad (6)$$

If $[vv]$ is the sum of the squares of the residuals obtained by subtracting the mean result for the station from the mean result for each pair, — then, e_p, the probable error of the mean result from any one pair is given, with sufficient accuracy, by the formula;

$$e_p = \sqrt{\frac{(0.455)\cdot[vv]}{p-1}} \qquad (7)$$

If n_1, n_2, n_3, etc. are the number of results used from the successive pairs and $\varepsilon^2 = \frac{e^2}{p}\left(\frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3} + \cdots + \frac{1}{n_p}\right)$ then the probable error of the mean of two declinations, e_δ , is given with sufficient accuracy by the formula;

$$e_\delta = \sqrt{e_p^2 - \varepsilon^2} \qquad (8)$$

The weights for the mean results from the separate indepen-

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*See, Hayford's Geodetic Astronomy, Art. 155.

dent pairs are proportional to;

$$\frac{1}{e_\delta^2+\frac{e^2}{n_1}},\ \frac{1}{e_\delta^2+\frac{e^2}{n_2}},\ \text{------}\ \frac{1}{e_\delta^2+\frac{e^2}{n_p}},$$

The most probable value of ϕ_0 is then given by the formula;

$$\phi_0=\frac{w_1\phi_1+w_2\phi_2+\text{---}+w_p\phi_p}{w_1+w_2+\text{---}+w_p} \qquad (9)$$

where w_1 and ϕ_1 are the weight and the mean result respectively for the first pair, w_2 and ϕ_2 for the second pair, and so on.

If $[w]$ is the sum of the weights and $[wv'^2]$ is the sum of the products of the weight for each pair by the square of the residual obtained by subtracting ϕ_0 from the mean result for that pair, —— then the probable error, e_ϕ, is given by the formula;

$$e_\phi=\sqrt{\frac{(0.455)[wv'^2]}{(p-1)[w]}} \qquad (10)$$

Tables IX and X give the values of the quantities used in the calculations of the most probable value of the latitude and its probable error. The computations themselves, in so far as they are not included in the tables, are given on page 59.

TABLE IX.

Values of $\Delta\Delta$.

Pair	Date 1909	" of ϕ	Δ +	Δ −	$\Delta\Delta$
III	July 8	39.61	2.113		4.465
	12	37.77	0.273		0.075
	14	35.11		2.387	5.698
n=	3)	112.49	2.386	2.387	10.238
Mean=		37.497			
V	12	38.48	0.948		0.899
	14	37.30		0.232	0.054
	17	35.32		2.212	4.893
	19	36.76		0.772	0.596
	21	38.66	1.128		1.272
	22	38.67	1.138		1.295
n=	6)	225.19	3.214	3.216	9.009
Mean =		37.532			
VI	17	37.81	1.105		1.221
	19	38.76	2.055		4.223
	21	34.69		2.015	4.060
	22	36.42		0.285	0.081
	24	32.35		4.355	18.966
	26	38.76	2.055		4.223
	27	37.19	0.485		0.235
	28	38.99	2.285		5.221
	Aug 2	35.65		1.055	1.113
	6	36.95	0.245		0.060
	9	36.19		0.515	0.265
n=	11)	403.76	8.230	8.225	39.668
Mean=		36.705			

Pair	Date 1909	" of ϕ	Δ +	Δ −	$\Delta\Delta$
VII	July 12	38.48	1.072		1.149
	14	36.88		0.528	0.280
	17	37.39		0.018	0.000
	19	37.06		0.348	0.121
	21	39.12	1.712		2.931
	22	37.81	0.402		0.162
	24	35.87		1.538	2.366
	26	38.23	0.822		0.676
	27	36.85		0.558	0.311
	28	37.35		0.058	0.003
	Aug 2	36.31		1.098	1.206
	6	37.73	0.322		0.104
	7	38.71	1.302		1.695
	9	36.37		1.038	1.077
	10	37.01		0.398	0.158
	12	37.35		0.058	0.003
n =	16)	598.52	5.632	5.640	12.242
Mean=		37.408			
VIII	July 12	39.58	3.212		10.317
	17	36.70	0.332		0.110
	19	35.98		0.388	0.151
	21	37.08	0.712		0.507
	22	36.79	0.422		0.178
	24	36.72	0.352		0.124
	26	36.79	0.422		0.178
	27	36.40	0.032		0.001
	28	36.49	0.122		0.015
	29	36.18		0.188	0.035
	30	35.02		1.348	1.817
	Aug 2	36.47	0.102		0.010
	6	37.53	1.162		1.350

Pair	Date 1909	" of ϕ	Δ +	Δ −	$\Delta\Delta$
	Aug 7	35.82		0.548	0.300
	9	36.70	0.332		0.110
	10	33.75		2.618	6.854
	11	35.65		0.718	0.516
	12	35.60		0.768	0.590
	14	35.75		0.618	0.382
n=	19)	691.00	7.202	7.194	23.545
Mean=		36.368			
IX_2	July 17	33.60		4.015	16.120
	21	39.62	2.005		4.020
	22	37.00		0.615	0.378
	24	36.80		0.815	0.664
	26	38.23	0.615		0.378
	27	38.66	1.045		1.092
	28	38.99	1.375		1.891
	30	37.16		0.455	0.207
	Aug 2	38.78	1.165		1.357
	6	38.54	0.925		0.856
	7	36.68		0.935	0.874
	9	38.08	0.465		0.216
	11	37.63	0.015		0.000
	14	36.84		0.775	0.601
n=	14)	526.61	7.610	7.610	28.654
Mean=		37.615			
X	July 22	37.57			0
n= 1					
XI	July 17	38.42	0.410		0.168
	21	37.82		0.190	0.036
	22	37.79		0.220	0.048
n=	3)	114.03	0.410	0.410	0.252
Mean		38.010			

Pair	Date 1909	" of ϕ	Δ +	Δ −	$\Delta\Delta$
XII	July 17	37.60	0.067		0.004
	21	38.04	0.507		0.257
	22	39.39	1.857		3.448
	24	37.73	0.197		0.039
	26	39.25	1.717		2.948
	27	36.75		0.783	0.613
	28	36.03		1.503	2.259
	30	37.05		0.483	0.233
	31	35.04		2.493	6.215
	Aug 2	41.17	3.637		13.228
	6	36.39		1.143	1.306
	7	38.91	1.377		1.896
	9	38.43	0.897		0.805
	10	35.88		1.653	2.732
	11	35.03		2.503	6.265
	12	39.11	1.577		2.487
	13	38.07	0.537		0.288
	14	35.75		1.783	3.179
n=	18)	675.62	12.370	12.344	48.202
Mean=		37.533			

Pair	Date 1909	" of ϕ	Δ +	Δ −	ΔΔ
XIII	July 17	38.80	0.522		0.272
	21	35.32		2.958	8.750
	22	38.06		0.218	0.048
	24	36.90		1.378	1.899
	26	38.55	0.272		0.074
	27	40.26	1.982		3.928
	28	37.31		0.968	0.938
	29	39.12	0.842		0.709
	30	38.22		0.058	0.003
	Aug 2	39.45	1.172		1.374
	6	37.35		0.928	0.861
	7	37.50		0.778	0.605
	9	38.07		0.208	0.043
	10	40.09	1.812		3.283
	11	39.87	1.592		2.534
	13	38.11		0.168	0.028
	14	37.75		0.528	0.279
	n = 17)	650.73	8.194	8.190	25.628
	Mean =	38.278			

Pair	Date 1909	" of ϕ	Δ +	Δ −	ΔΔ
XIV	July 17	36.17	0.602		0.362
	21	36.29	0.722		0.521
	22	35.47		0.098	0.010
	24	35.15		0.418	0.175
	26	35.86	0.292		0.085
	27	32.66		2.908	8.456
	28	35.40		0.168	0.028
	29	35.82	0.252		0.064
	30	36.92	1.352		1.828
	Aug 2	33.78		1.788	3.197
	6	38.63	3.062		9.376
	7	33.88		1.688	2.849
	9	35.85	0.282		0.080
	10	35.36		0.208	0.043
	11	34.98		0.588	0.346
	13	34.70		0.868	0.753
	14	37.73	2.162		4.674
	n = 17)	604.65	8.726	8.732	32.847
	Mean =	35.568			

Pair	Date 1909	" of ϕ	Δ +	Δ −	ΔΔ
XVI 2	July 21	35.36		0.608	0.370
	22	36.01	0.042		0.002
	27	37.27	1.302		1.695
	Aug 14	35.23		0.738	0.545
	n = 4)	143.87	1.344	1.346	2.612
	Mean =	35.968			
XVI 4	July 21	37.23	0.250		0.062
	22	36.73		0.250	0.062
	n = 2)	73.96			0.124
	Mean =	36.980			
XVI 5	July 21	37.83	1.145		1.311
	22	35.54		1.145	1.311
	n = 2)	73.37			2.622
	Mean =	36.685			
XVI 6	July 24	36.30		1.427	2.036
	26	36.91		0.817	0.667
	27	38.55	0.823		0.677
	28	37.43		0.297	0.088
	30	38.14	0.413		0.171
	Aug 2	38.38	0.653		0.426
	6	36.67		1.057	1.117
	7	37.60		0.127	0.016
	10	38.47	0.743		0.552
	11	37.45		0.277	0.077
	13	40.71	2.983		8.898
	14	36.11		1.617	2.615
	n = 12)	452.72	5.615	5.619	17.340
	Mean =	37.727			

Pair	Date 1909	" of ϕ	Δ +	Δ −	ΔΔ
XVII	July 28	39.43			0
	n = 1				

TABLE X.

Means, residuals, weights, etc.

Pair	n	$\Sigma\Delta\Delta$	Mean " of ϕ	v +	v −	vv	$\frac{1}{n}$	$\log\frac{1}{n}$	$\log\frac{e^2}{n}$	$\frac{e^2}{n}$	$e_\delta^2+\frac{e^2}{n}$	$\frac{1}{e_\delta^2+\frac{e^2}{n}}$	w	$w\phi$	v' +	v' −	v'^2	wv'^2
III	3	10.238	37.497	0.192		0.037	0.333	9.52244	9.46960	0.295	0.433	2.309	23	862.431	0.296		0.088	2.024"
V	6	9.009	37.532	0.227		0.052	0.167	9.22272	9.16988	0.148	0.286	3.496	35	1313.620	0.331		0.110	3.850
VI	11	39.668	36.705		0.600	0.360	0.091	8.95904	8.90620	0.081	0.219	4.566	46	1688.430		0.496	0.246	11.316
VII	16	12.242	37.408	0.103		0.011	0.062	8.79239	8.73955	0.055	0.193	5.181	52	1945.216	0.207		0.043	2.236
VIII	19	23.545	36.368		0.937	0.878	0.053	8.72428	8.77144	0.059	0.197	5.076	51	1854.768		0.833	0.694	35.394
IX_2	14	28.654	37.615	0.310		0.096	0.071	8.85126	8.79842	0.063	0.201	4.975	50	1880.750	0.414		0.171	8.550
X	1	0	37.570	0.265		0.070	1.000	0.00000	9.94716	0.885	1.023	0.978	10	375.700	0.369		0.136	1.360
XI	3	0.252	38.010	0.705		0.497	0.333	9.52244	9.46960	0.295	0.433	2.309	23	874.230	0.809		0.654	15.042
XII	18	48.202	37.533	0.228		0.052	0.056	8.74819	8.69535	0.050	0.188	5.319	53	1989.249	0.332		0.110	5.830
XIII	17	25.628	38.278	0.973		0.947	0.059	8.77085	8.71801	0.052	0.190	5.263	53	2028.734	1.077		1.160	61.480
XIV	17	32.847	35.568		1.737	3.017	0.059	8.77085	8.71801	0.052	0.190	5.263	53	1885.104		1.633	2.667	141.361
XVI_2	4	2.612	35.968		1.337	1.788	0.250	9.39794	9.34501	0.221	0.359	2.786	14*	563.552		1.233	1.520	21.280
XVI_4	2	0.124	36.980		0.325	0.106	0.500	9.69897	9.64613	0.443	0.581	1.721	9*	332.820		0.221	0.049	0.441
XVI_5	2	2.622	36.685		0.620	0.384	0.500	9.69897	9.64613	0.443	0.581	1.721	12*	440.220		0.516	0.266	3.192
XVI_6	12	17.340	37.727	0.422		0.178	0.083	8.91908	8.86624	0.073	0.211	4.739	16*	603.632	0.526		0.277	4.432
XVII	1	0	39.430	2.125		4.516	1.000	0.00000	9.94716	0.885	1.023	0.978	10	394.300	2.229		5.244	52.440
16	146	252.983	596.874 ÷ 16 = 37.305	5.550	5.556	12.989	4.617						510	18972.756				370.218
p	n	$[\Delta\Delta]$	Mean			$[vv]$	$\Sigma\frac{1}{n}$						$[w]$	$[w\phi]$				$[wv'^2]$

*Note on weights of pairs XVI_2, XVI_4, XVI_5 and XVI_6: The stars of these pairs are as follows, (Safford numbers being used):

XVI_2 {811, 832

XVI_4 {811, 852

XVI_5 {796, 856

XVI_6 {811, 856

Hence the values of $\frac{1}{e_\delta^2+\frac{e^2}{n}}$ are in these cases multiplied by $\frac{1}{2}$, $\frac{1}{2}\cdot\frac{2}{3}$, and $\frac{1}{2}\cdot\frac{2}{3}=\frac{1}{3}$ respectively; since one star of each of the first two pairs occurs in two other pairs, one star of the third pair occurs in one other pair, and in the case of the 4th pair one of the stars occurs in two other pairs while the other occurs in one other pair. (See Hayford p. 172)

Probable error, ϱ , of a single observation;

log0.455	9.658011
log $[\Delta\Delta]$	2.403091
colog(n-p)	7.886057
log ϱ^2	9.947159
log ϱ	9.973580
ϱ^2	$0\overset{''}{.}885$
ϱ	$\pm 0\overset{''}{.}941$

Probable error, ϱ_p , of the mean result from any one pair;

log(0.455)	9.658011
log $[vv]$	1.113576
colog(p-1)	8.823909
log ϱ_p^2	9.595496
log ϱ_p	9.797748
ϱ_p	$\pm 0\overset{''}{.}628$

Probable error, ϱ_δ , of the mean of two declinations;

log ϱ^2	9.947159
log $\Sigma\frac{1}{m}$	0.664360
colog p	8.795880
log ε^2	9.407399
ε^2	$0\overset{''}{.}256$
ϱ_p^2	$0\overset{''}{.}394$
ϱ_δ^2	$0\overset{''}{.}138$
ϱ_δ	$\pm 0\overset{''}{.}371$

Most probable value, ϕ_0 , of the latitude;

(18972.756÷510 =37.201) $42^\circ\ 22'\ 37\overset{''}{.}201$

Probable error, ϱ_ϕ , of the latitude;

log (0.455)	9.658011	log ϱ_ϕ^2	8.342808
log $[wvv'^2]$	2.568458	log ϱ_ϕ	9.171404
colog(p-1)	8.823909		
colog $[w]$	7.292430	ϱ_ϕ	$\pm 0\overset{''}{.}148$

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Note on the use of books.

Chauvenet's Astronomy was used throughout as a general guide in all theoretic work, particularly in Sections I and II. Hayford's Astronomy was used as a guide in the matter of technical details in the main problem of the paper, particularly in Sections III, IV, and VI. Young, Loomis, and Greene, were read in connection with the discussion of Section I.

The Safford and Ambronn catalogues were used in selecting the original star-list, (See Table II.), and with the other catalogues were consulted in determining the final values of the declinations in Section V.

OBSERVATORY NOTES.

July 8, 1909

	Level N	Level S	Micr.	
II	52.7	18.	12.339	
	Lost			
III	16.0	50.9	4.018	
			24.018 ?	III
	51.2	17.2	12.274	Poor illumination ✓
IV	18.3	53.0	32.360	IV ✓
	51.5	16.9	3.728	Wire III
V	18.0	53.2	27.465	Wire IV ✓
	53.0	18.0	10.841	Wire II
VI				

R. E. Bruce.

July 12, 1909

Br	Level N	S	Micr *	Wr	
II	50.1	18.0	17.288	II	✓
	18.6	50.4	19.797	IV	
III	18.4	50.3	24.153	III	✓
	51.5	19.5	12.510		Image unsteady
V	18.7	50.8	27.149	III	(Pair IV lost in adjusting lights) ✓
	57.0	24.8	10.884		
VI	South end of bubble beyond scale!				
VII	18.6	51.4	20,385	III	✓
	51.3	18.4	17.460		
VIII	44.3	11.4	20.880	III	Two stars of equal mag. near together. One taken has less δ and less α. Bisection rough. Image unsteady ✓
	16.8	49.6	14.641		
IX	Couldn't find stars! Scale set on wrong side!			II	This is the correct star.
X	51.7	18.8	12.810	III	
	Clouds				

* All readings on wire III.

R. E. Bruce

July 14, 1909

Br	Level N	Level S	Mic	Wire Obs. Read.	
III	18.0	47.5	24.220	III	✓
	47.7	18.1	12.653		
IV	20.3	49.9	32.374	IV	✓
	43.6	14.0	3.630	II	III reads 13.630
V	17.0	46.8	27.129	III	✓
	48.5	18.4	10.788	III	
VI	Clouds!				
VII	18.4	49.0	20.309(5)	III	✓
	51.0	20.2	17.514	III	
VIII	Lost!				
IX	First star lost on account of clouds				
	20.8	51.1	26.753	III	Rough bisection. Clouds!
	Clouds!				

R. E. Bruce

July 17, 1909

Pr	Level N	Level S	Micr	Wire Obs. Read		
V	18.1	48.4	26.928	III		✓
	47.1	16.6	10.592			
VI	13.0	43.8	17.160	III		✓
	42.4	16.3	19.663			
VII	18.1	49.2	20.297	III		✓
	49.2	18.1	17.450			
VIII	49.7	18.6	21.346	III	* ←	✓
	19.1	50.3	14.833			
IX	49.7	18.2	7.211	II		✓
	16.2	48.0	26.787	III		
	51.3	19.8	23.866	III	Poor bisection. Light cloud	
X					Lost. Light clouds.	
XI	16.7	48.8	11.237	III		✓
	50.6	18.0	24.456			
XII	16.5	49.1	20.484	III		✓
	51.0	18.0	14.582			
XIII	49.2	16.4	16.845	III		✓
	16.8	49.7	19.186			
XIV	18.8	51.6	15.847	III		✓
	51.8	18.7	19.505			
XV	15.9	48.8	6.535	II		✓
	44.0	10.7	29.286	IV		

R E Bruce.

July 19, 1909

Pr	Levels N	Levels S	Micr	Wire Obs Rd	
IV	11.4	46.3	32.204	IV	✓
	51.3	16.0	3.782	II	Rough bisection. Light cloud.
V	13.0	48.5	26.965	III	✓
	54.1	18.4	10.780	III	
VI	15.8	51.6	17.101	III	✓
	54.2	18.0	19.550	III	
VII	15.2	51.2	20.154	III	✓
	52.6	16.6	17.372	III	
VIII	20.2	56.3	21.130	III	✓
	54.3	18.2	14.508	III	
IX	50.0	14.0	7.113	II	✓
	14.0	50.0	26.673	III	

Work discontinued. Lights out!

R. E. Bruce

Pr	N Levels S		Mics	Wire Obs. Rd	July 21, 1909 (1)	
IV	13.0	49.0	32.010	IV		✓
	52.7	16.6	3.545	II		
V	13.0	49.4	26.823	III	Image unsteady	✓
	47.1	10.8	10.359	III		
VI	15.8	52.5	17.294	III		✓
	54.5	17.7	19.890	III	Image unsteady	
VII	16.8	53.7	20.186	III		✓
	52.8	16.0	17.276	III	Image unsteady	
VIII	55.4	18.5	21.209	III		✓
	17.4	54.3	14.641	III		
IX	50.0	13.0	7.130	II		
	17.5	54.4	26.861	III		✓
	50.1	13.0	23.522	III		
X	48.9	16.9	12.604	III		
	18.6	55.6	24.573	IV		✓
XI	16.8	54.4	11.140	III		✓
	54.3	16.6	24.357	III		
XII	18.2	56.3	20.535	III		✓
	54.5	16.5	14.549	III	Image unsteady	
XIII	54.5	16.5	16.744	III		✓
	18.1	56.3	18.945	III		
XIV	16.4	54.4	15.805	III		
	54.2	16.0	19.473	III		✓
XV	16.0	54.0	6.538	II		✓
	54.3	16.2	29.405	IV		

July 21, 1909
②

Pn	Level N	Level S	Micr	Wire Obs	Wire Rd	
	56.7	18.5	28.501	IV		
	54.5	16.4	17.131	III		
	13.0	51.2	12.651	III		Rough bisection ✓
XVI	16.0	54.3	7.756	III		
	16.0	54.3	22.310	IV		

Slight haze made work with
6 mag troublesome.

R. E. Bruce.

July 22, 1909

1

Pr	Level N	Level S	Micr	Wire Obs	Wire Rd		
V	17.0	54.0	26.946	III			✓
	55.3	18.0	10.582	III			
VI	16.9	54.5	17.546	III			✓
	54.7	16.8	20.032	III			
VII	16.8	54.2	20.280	III			✓
	55.4	17.8	17.478	III		Image unsteady	
VIII	54.4	16.8	21.316	III		Bisection rough	
	16.8	54.3	14.762	III			✓
IX	54.4	16.7	7.142	II			✓
	16.8	54.5	26.802	III			
	54.6	16.8	23.689	III			
X	54.4	16.5	12.610	III			✓
	20.0	58.0	24.428	III			
XI	12.0	50.8	10.989	III			✓
	51.0	12.2	24.224	III			
XII	15.7	54.6	20.472	III			✓
	49.3	10.5	14.346	III			
XIII	57.0	18.1	16.767	III			✓
	13.0	51.8	18.874	III		5 mag 10 below in 30 s.	
XIV	15.4	54.4	15.513	III			✓
	57.0	18.1	19.302	III			
XV	12.7	51.9	6.324	II			✓
	56.8	18.0	29.320	IV		Bisection rough	

Bn	Level N.	Level S	Micr	Wire Obs. Rd	July 22, 1909 ②
	54.5	15.6	28.619	IV	
	54.5	15.8	17.291	III	✓
XVI	15.5	54.5	12.916	III	
	15.2	54.5	7.889	III	
	15.2	54.5	22.400	IV	Rough bisection

R. E. Bruce

Pr	N.S.	Level N	Level S	Micr	Wire Ob. Rd	July 24, 1909 ①
V	S	18.0	53.4	27.083	III	✓
	N	49.5	14.0	10.725	II	
VI	S	15.7	51.3	17.150	III	✓
	N	54.6	18.8	19.882	III	Very rough bisection. Clouds!
VII	S	18.2	54.0	20.141	III	✓
	N	54.2	18.2	17.394	III	
VIII	N	54.0	18.0	21.288	III	✓
	S	16.8	52.0	14.659	III	
IX	N	51.8	15.6	7.059	II	✓
	S	16.0	52.3	26.614	III	
	N	53.2	16.6	23.545	III	
X	N	53.3	16.6	12.867	III	✓
	S	14.7	51.3	24.676	IV	
XI	S	13.9	51.0	11.163	II	✓
	N	51.3	14.0	24.402	III	
XII	S	13.0	50.4	20.465	III	Image unsteady ✓
	N	54.2	16.8	14.672	III	
XIII	N	51.9	14.2	16.987	III	✓
	S	16.6	54.3	19.248	III	5 mag at about 13, 3m later
XIV	S	16.7	53.5	15.613	III	Image unsteady ✓
	N	54.6	16.7	19.388	III	
XV	S	15.6	53.7	6.631	II	✓
	N	54.0	16.0	29.544	IV	

Pr	N.S	Level N.	Level S.	Micr	Wire Ob. Rd.	July 24, 1909 ②
XVI	N	54.4	16.3	28.715	IV	V
	N	54.4	16.2	17.443	III	
	S	16.0	54.4	13.046	II	
	S	16.0	54.3	8.017	II	
	S	16.0	54.3	22.402	III	Image unsteady
XVII	S	15.3	53.9	15.258	III	
	N	Lost (Time)				

R. E. Bruce.

Pr	N.S.	Level N.	Level S.	Micr	Wire	July 26, 1909
V	S	14.0	46.5	26.974	III	Bisection rough.
	N	46.7	14.0	10.734	II	✓
VI	S	16.0	48.8	17.360	III	
	N	51.3	18.0	19.845	III	✓
VII	S	16.8	49.8	20.117	III	
	N	49.7	16.2	17.285	III	✓
VIII	N	51.2	18.0	21.120	III	
	S	16.7	50.0	14.503	III	✓
IX	N	48.7	14.8	7.066	II	
	S	16.8	50.6	26.674	III	✓
	N	50.0	15.8	23.527	III	
X	N	50.8	16.7	12.708	II	✓
	S	12.3	46.5	24.311	III	Image unsteady.
XI	S	15.9	50.6	11.124	II	
	N	50.8	15.8	24.433	III	✓
XII	S	16.8	51.8	20.617	III	Image unsteady.
	N	53.6	18.0	14.722	III	✓
XIII	N	51.3	15.8	16.713	III	
	S	18.0	54.7	19.028	III	✓
XIV	S	16.3	51.8	15.777	III	
	N	52.2	16.6	19.526	III	✓
XV	S	16.9	52.4	6.510	II	✓
	N	58.8	22.8	29.558	IV	Rough bisection
XVI	N	52.8	16.8	28.656	IV	
	N	51.8	16.0	17.352	III	
	S	15.8	51.8	12.895	II	✓
	S	15.8	51.8	7.870	II	
	S	14.3	50.3	22.271	III	
XVII	S	15.0	51.2	15.112	III	✓
	N	53.0	16.8	22.779	IV	Rough bisection R. E. Prince.

July 27, 1909

Pr	N.S	Level N.	Level S.	Micr	Wire	
VI	S	16.8	49.8	17.175	III	✓
	N	50.0	16.7	19.664	III	
VII	S	18.2	51.4	20.161	III	✓
	N	51.2	17.8	17.387	III	
VIII	N	51.2	17.8	21.015	III	✓
	S	16.8	50.1	14.382	III	
IX	N	50.2	16.8	7.170	II	✓
	S	15.8	49.7	26.613	III	
	N	49.7	15.8	23.482	III	
X	N	49.9	16.0	12.744	II	Light clouds. ✓
	S	15.8	49.7	24.400	III	
XI	S	16.1	50.2	11.078	II	✓
	N	49.6	15.6	24.346	III	
XII	S	16.4	51.3	20.431	III	✓
	N	51.7	16.8	14.605	III	
XIII	N	50.8	16.0	16.741	III	Before observation level stood: N 16.3 S 51.3 ✓
	S	19.5	54.5	19.132	III	
XIV	S	15.8	50.7	15.567	III	✓
	N	51.3	16.3	19.449		
XV	S	14.0	49.0	6.520	II	✓
	N	49.0	14.0	29.448	IV	
XVI	N	51.0	15.8	28.489	IV	✓
	N	49.2	14.0	17.173	III	
	S	16.0	51.3	12.853	III	
	S	16.0	51.3	7.848	II	
	S	16.0	51.3	22.244	III	
XVII	S	15.7	51.2	15.207	III	✓
	N	52.3	16.7	22.738	IV	Image unsteady

R. E. Bruce

Pr	N,S.	Level N.	Level S.	Mirror	Wire	July 28, 1909
VI	S	16.7	49.2	17.196	III	✓
	N	48.7	15.8	19.599		
VII	S	16.8	49.7	20.188	III	✓
	N	49.9	16.7	17.412		Rough bisection.
VIII	N	47.5	14.2	21.329	III	✓
	S	14.0	47.5	14.722		
IX	N	49.6	16.0	7.306	II	Estimated from length of bubble.
	S	18.3	51.7	26.921	III	✓
	N	48.8,	16.1	23.711	III	
X	N	49.2.,	15.7	21.630	III	✓
	S	31.1,	64.6	33.922	IV	Bisection rough setting 1°31',
XI	S	14.0,	48.2	10.759	II	✓
	N	50.2,	15.7	24.070	III	
XII	S	15.8	50.3	20.576	III	✓
	N	50.8	16.0	14.782	III	
XIII	N	49.3,	15.7	16,794	III	✓
	S	16.0,	49.6	18.977	III	
XIV	S	16.0	50.8	15.235	III	✓
	N	51.3	16.3	19.020	III	
XV	S	15.8	50.8	6.598	II	✓
	N	51.2	16.0	29.567	IV	
XVI	N	51.1	15.8	28.627	IV	✓
	N	51.8	16.0	17.317	III	
	S	15.4	51.2	12.896	II	
	S	15.3	51.2	7.865	II	
	S	15.2	51.1	22.259	III	
XVII	S	15.0	51.2	15.328	III	✓
	N	49.2	14.0	22.694		R.E. Brance {assisted by P. L. Grier.

July 29, 1909

Pr	N, S	Level N	Level S	Micr	Wire	
VIII	N	50.0	18.2	21.103	III	
	S	18.2	50.2	14.486	III	✓
IX	N	49.3	16.8	7.110	II	
	S	Clouds!			III	✓
	N					
X	N	49.6	15.8	12.461	II	Bisection very rough ✓
	S	16.0	49.8	24.371	III	Clouds!!
XI	S	16.0	50.2	11.300	II	✓
	N	47.4	13.8	24.517	III	
XII	S	Lost, Clouds!				✓
	N					
XIII	N	51.3	16.2	16.502	III	✓
	S	16.2	51.3	18.734	III	
XIV	S	16.1	51.3	15.314	III	✓
	N	51.3	16.0	19.079	III	
XV	S	Clouds!				✓
	N					

R. E. Bruce

Assisted by P. L. Grier.

July 30, 1909

		Level N	Level S	Micr	Mic		
VIII	N	48.8	16.7	21.170	III		✓
	S	16.7	48.9	14.505	III		
IX	N	48.8	16.0	7.171	II		✓
	S	13.8	46.8	26.568	III		
	N	49.1	16.0	23.570	III		
X	N	50.0	16.8	12.680	II	Rough, dis. Clouds!	✓
	S	Missed!					
XI	S	18.3	52.0	11.310	II		✓
	N	50.8	16.8	24.536	III		
XII	S	16.8	50.5	20.369	III		✓
	N	51.2	17.1	14.558	III		
XIII	N	52.4	18.2	16.916	III		✓
	S	17.6	51.8	19.090	III		
XIV	S	16.8	51.3	15.523	III		✓
	N	50.5	16.0	19.235	III		
XV	S	18.2	53.2	6.320	II		✓
	N	46.8	12.0	28.336	IV		
XVI	N	51.3	16.8	28.601	IV		✓
	N	50.4	15.8	17.242	III		✓
	S	16.5	51.3	12.828	II		
	S	16.4	51.3	7.830	II		
	S	16.3	51.3	22.232	III		
XV	S	16.0	51.0	14.938	III		✓
	N	51.3	16.3	22.611	IV		

XVII

R. E. Bruce

Pr		Level N	Level S	Micr	Wire	July 31, 1909
XII	S	18.0	52.4	20.580	III	
	N	53.0	18.4	14.848	III	Bisection rough: clouds! ✓

Clouds prevented observation of other pairs earlier and later.

R. E. Bruce

Aug 2, 1909

		Level N	Level S	Micr	Wire	
IV	S	18.2	52.8	32.156	IV	
	N	Star too dim				
V	S	15.2	50.8	26.695	III	r
	N	51.3	15.4	10.745	II	
VI	S	18.0	54.0	17.253	III	r
	N	54.6	18.0	19.824	III	
VII	S	18.0	54.3	20.111	III	r
	N	54.5	18.0	17.394	III	
VIII	N	54.5	18.0	21.181	III	r
	S	18.0	54.4	14.553	III	
IX	N	52.6	15.9	7.133	II	
	S	49.5	17.8	26.731	III	r
	N	16.0	52.8	23.576	III	
X	N	54.5	17.5	12.717	II	r
	S	16.8	53.8	24.340	III	
XI	S	16.7	54.0	11.169	II	r
	N	54.2	16.8	24.490	III	
XII	S	16.5	54.4	20.298		r
	N	54.0	16.0	14.330	III	
XIII	N	54.2	16.0	16.711	III	r
	S	16.0	54.2	18.923	III	
XIV	S	16.1	54.3	15.569	III	r
	N	54.3	16.0	19.439	III	
XV	S	16.0	54.3	6.486	II	i
	N	54.4	15.7	29.366	IV	
XVI	N	54.5	15.6	28.438	IV	
	N	54.3	15.4	17.125	III	r
	S	15.2	54.4	12.700	II	
	S	15.1	54.3	7.699	II	
	S	15.1	54.3	22.073	III	
XVII	S	15.2	54.3	15.126	III	r
	N	51.1	11.9	22.622	IV	

R. E. Bruce
P. L. Grier

Aug 6, 1909

Pr		Level N	Level S	Micr	Wire	
VI	S	13.1	48.9	16.909	III	✓
	N	49.0	13.1	19.439	III	
VII	S	15.2	51.2	19.820	III	✓
	N	51.3	15.1	17.064	III	
VIII	N	53.0	16.7	21.230	III	✓
	S	15.4	51.8	14.591	III	
IX	N	53.3	16.7	7.198	II	✓
	S	17.8	54.4	26.741	III	
	N	54.4	17.4	23.657	III	
X	N	53.8	16.7	12.673	II	✓
	S	16.7	54.0	24.323	III	
XI	S	17.1	54.4	10.957	II	✓
	N	54.3	16.8	24.234	III	
XII	S	16.5	54.4	20.150	III	✓
	N	54.4	16.5	14.393	III	
XIII	N	54.4	16.5	16.700	III	✓
	S	16.0	53.9	18.805	III	
XIV	S	16.4	54.4	15.542	III	✓
	N	54.1	16.0	19.255	III	
XV	S	18.3	56.8	6.368	II	Bisection rough. Clouds! ✓
	N	56.7	18.1	29.362	IV	
XVI	N	54.4	15.8	28.377	IV	✓
	N	54.3	15.8	17.084	III	
	S	15.8	54.3	12.583	II	
	S	15.2	54.0	7.554	II	
	S	15.2	54.0	21.930	III	
XVII	S	16.2	55.0	15.024	III	✓
	N	46.7	7.7	22.410	IV	Image unsteady

R. E. Bruce

Aug 7, 1909.

Pr	N.S	Level N	Level S	Micr	Wire	
VII	S	13.0	46.7	19.920	III	✓
	N	49.6	15.8	17.213	III	
VIII	N	*	17.2	20.862	III	* Bubble moved before reading could be completed. ✓
	S	18.0	51.2	14.214	III	
IX	N	49.3	15.7	7.123	II	✓
	S	15.8	49.4	26.557	III	
	N	50.7	16.7	23.583	III	
X	N	49.9	15.8	12.493	II	✓
	S	16.8	51.0	24.216	III	
XI	S	18.0	52.6	10.923	II	✓
	N	52.9	18.1	24.304	III	
XII	S	16.4	51.3	20.357	III	✓
	N	51.3	16.1	14.510	III	
XIII	N	49.2	14.0	16.481	III	✓
	S	15.9	51.2	18.641	III	
XIV	S	16.0	51.2	15.302	III	✓
	N	52.2	16.9	19.232	III	
XV	S	16.0	51.3	6.227	II	✓
	N	51.8	16.3	29.219	IV	
XVI	N	51.3	15.9	28.597	IV	✓
	N	51.3	15.9	17.264	III	
	S	15.7	51.3	12.800	II	
	S	15.7	51.3	7.780	II	
	S	15.7	51.3	22.144	III	
XVII	S	16.8	52.4	15.148	III	✓
	N	54.4	18.7	22.962	IV	

R. E. Bruce

Aug 9, 1909.

Pair	N.S	Level N.	Level S.	Micr	Wire	
VI	S	15.7	47.5	17.090	III	Stars very dim; bisections difficult
	N	46.0 *	13.7	19.608	III	* Bubble moving when read ✓
VII	S	50.6	18.1	20.240	III	✓
	N	18.2	51.0	17.554	III	
VIII	N	16.7	49.3	21.132	III	✓
	S	51.2	18.6	14.538	III	
IX	N	48.8	15.8	7.162	II	✓
	S.	14.3	47.4	26.609	III	
	N	49.3	16.0	23.615	III	Image unsteady
X	N	46.5	13.0	12.597	II	✓
	S	17.8	51.3	24.368	III	
XI	S	16.7	50.4	11.002	II	✓
	N	50.1	16.3	24.374	III	
XII	S	16.0	50.1	20.164	III	Rough bisection. Image unsteady & clouds
	N	50.0	15.8	14.346	III	
XIII	N	54.0 *	18.8	16.830	III	* Bubble moving when read. ✓
	S	16.9	51.2	18.875	III	
XIV	S	16.9	51.3	15.503	III	✓
	N	50.3	16.0	19.324	III	
XV	S	16.0	50.4	6.372	II	✓
	N	52.8	18.0	29.453	IV	
XVI	N	51.3	16.5	28.408	IV	✓
	N	51.0	16.0	17.092	III	
	S	16.3	51.2	12.590	II	
	S	Lost. Clouds!				
	S	Lost.				
XVIII	S	Lost.				
	N					

R. E. Bruce.

Aug 10, 1909

Pr	N.S	Level N.	Level S.	Micr	Wire		
VII	S	16.5	51.3	20.150	III		✓
	N	53.4	18.0	17.488	III		
VIII	N	53.6	18.0	20.995	III		✓
	S	18.0	53.9	14.240	III		
IX	N S N	missed.		Clouds!			
X	N	53.9	16.8	12,816	II	Rough bisection, Clouds!	✓
	S	18.6	55.7	24.447	III		
XI	S	13.0	50.7	10.876	II		✓
	N	49.2	11.4	24.161	III		
XII	S	16.2	54.3	20.232	III		✓
	N	54.3	16.0	14.514	III		
XIII	N	56.6	18.0	16.679	III		✓
	S	16.0	54.4	18.797	III		
XIV	S	15.7	54.3	15.401	III		✓
	N	55.3	16.7	19.303	III		
XV	S	15.8	54.4	6.215	II		✓
	N	54.4	15.8	29.288	IV		
XVI	N	53.0	14.0	28.532	IV		✓
	N	53.0	14.0	17.213	III		
	S	13.0	52.0	12.662	II		
	S	11.4	50.7	7.633	II		
	S	11.4	50.7	22.028	III		
XVII	S	12.0	51.3	15.015	III		✓
	N	53.2	14.0	22.708	IV		

R. E. Bruce

Aug 11, 1909.

Pr	N. S	Level N.	S.	Micr.	Wire.	
VIII	N	49.0	13.0	20,809	III	√
	S	15.1	51.3	14.176	III	
IX	N	50.1	14.0	6.995	II	√
	S	13.0	49.3	26.428	III	
	N	50.4	14.0	23.440	III	
X	N	54.3	17.8	12,760	II	√
	S	17.8	54.4	24.400	III	
XI	S	Lost. Clouds!				
	N					
XII	S	16.7	54.0	20.394	III	√
	N	54.4	16.8	14.722	III	
XIII	N	51.8	14.0	16.670	III	√
	S	13.5	51.3	18.818	III	
XIV	S	16.2	54.0	15.495	III	√
	N	54.4	16.5	19.400	III	
XV	S	14.5	52.7	6.374	II	√
	N	47.6	9.5	29.269	III	Rough. Image unsteady
XVI	N	51.1	13.0	28.504	IV	
	N	51.2	13.0	17.205	III	√
	S	12.0	50.7	12.631	II	
	S	12.0	51.0	7.635	II	Image unsteady
	S	12.0	51.0	22.025	III	
XVII	S	11.4	50.3	14,760	III	√
	N	53.2	14.0	22,546	IV	

R. E. Bruce.

Aug 12, 1909

Dr	N.S.	Level N.	Level S.	Micr.	Wire	
VII	S	16.3	50.3	20.196	III	✓
	N	48.3	14.0	17.419	III	
VIII	N	51.2	16.7	21.186	III	✓
	S	16.3	51.1	14.478	III	
IX	N	Missed. Heavy haze.				
	S					
	N					
XI	S	16.7	53.0	11.090	II	
	N	54.4	18.0	24.547	III	✓
XII	S	17.5	54.4	20.430	III	✓
	N	53.9	16.7	14.591	III	Rough, Heavy haze.

R. E. Bruce,

Pr	N.S	Level N	S.	Micr.	Wire	Aug 13, 1909
X	N	51.0	14.0	12.728	II	✓
	S	14.3	51.2	24.346	III	
XI	S	14.0	51.3	10.988	II	✓
	N	51.2	13.6	24.359	III	
XII	S	11.5	49.5	20.085	III	✓
	N	49.6	11.3	14.307	III	
XIII	N	53.3	15.1	16.820	III	✓
	S	15.8	54.0	18.927	III	
XIV	S	16.0	54.4	15.559	III	✓
	N	54.4	16.0	19.475	III	
XV	S	13.0	51.8	6.587	II	✓
	N	54.4	15.8	29.690	IV	
XVI	N	54.0	15.0	28.434	IV	
	N	54.0	15.0	17.107	III	✓
	S	15.2	54.3	12.657	II	
	S	15.1	54.3	7.672	II	
	S	15.1	54.3	22.056	III	
XVII	S	15.9	55.1	15.020	III	✓
	N	54.4	15.0	22.759	IV	

R. E. Bruce

Aug 14, 1909

Pr	N.S	Level N	Level S	Micr	Wire		
VIII	N	51.8	16.0	21.010	III		
	S	15.5	51.3	14.291	III		✓
IX	N	51.2	15.1	7.055	II		
	S	15.0	51.2	26.471	III		✓
	N	51.2	14.6	23.484	III	Image unsteady	
X	N	51.0	14.0	12.677	II		
	S	14.1	51.2	24.297	III		✓
XI	S	14.1	51.8	10.914	II		
	N	54.0	16.3	24.350	III		✓
XII	S	16.0	54.0	20.373	III		✓
	N	54.4	16.0	14.692	III		
XIII	N	54.4	16.0	16.822	III		✓
	S	16.0	54.4	18.891	II		
XIV	S	15.8	54.4	15.671	III		✓
	N	57.0	18.0	19.551	III		
XV	S	11.7	50.8	6.272	II	Image unsteady.	✓
	N	54.5	15.5	29.513	IV		
XVI	N	54.0	15.0	28.559	IV		
	N	54.3	15.0	17.242	III		✓
	S	14.8	54.3	12.634	III		
	S	14.7	54.3	7.629	II		
	S	14.4	54.0	22.000	III		
XVII	S	14.5	54.4	15.100	III		
	N	55.0	15.1	22.834	IV		✓

R. E. Bruce